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# MINING MACHINERY.

JORDAN'S PATENT "CENTRIFUGAL" GOLD PROCESS.

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PATENT "TRURO" POWER ROCK DRILL & AIR COMPRESSORS.

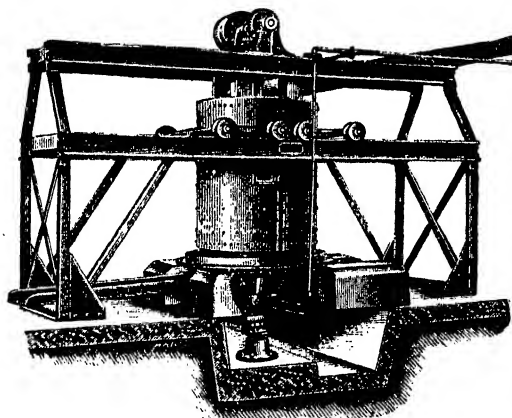
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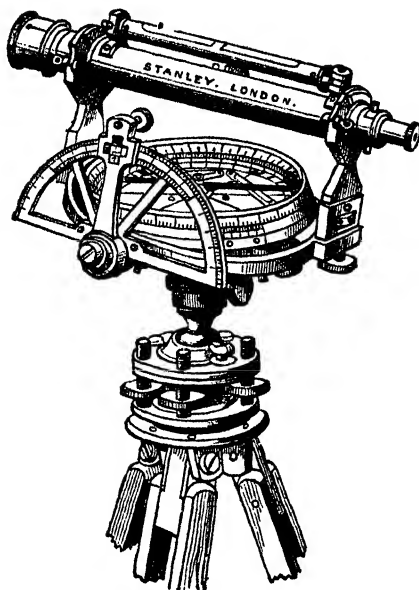
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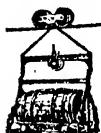
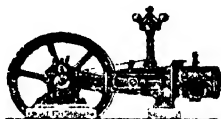


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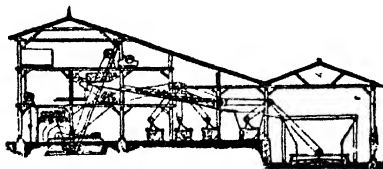


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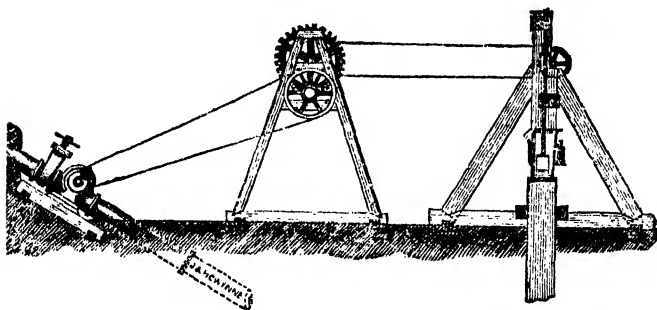
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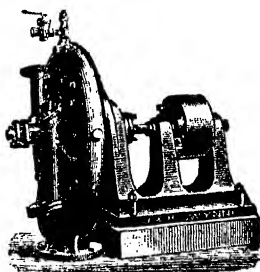


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MINERALOGISTS, MILLMEN, ASSAYERS, METALLURGISTS,  
AND METAL MERCHANTS, ALL OVER THE WORLD.

C. G. WARNFORD LOCK,

MEMBER OF COUNCIL OF THE INSTITUTION OF MINING AND METALLURGY,  
AUTHOR OF 'PRACTICAL GOLD MINING,' ETC.



E. & F. N. SPON, 125, STRAND, LONDON.

NEW YORK: 12, CORTLANDT STREET.

1892.



## INTRODUCTION.

WHILST the wants of Civil and Mechanical Engineers are provided for by such handy and valuable works of reference as the "pocket-books" of Molesworth, Hurst, and other well-known authors, the needs of the MINING ENGINEER in the same direction have hitherto been disregarded. Yet, by the nature of his calling the last-named is generally less able to furnish himself with a library, and certainly quite as often is confronted with problems and difficulties, when the means of refreshing the memory with forgotten formulæ or figures is very acceptable.

The preparation of the present little volume has been undertaken with a view of supplying the want, and with a desire to embrace under one pair of covers information on the many and various branches of science with which the Mining Engineer is called upon at times to make himself familiar. Furthermore the economic or commercial side of the industry has not been overlooked, for the ultimate aim of all mining is financial gain.

Obviously it would be impossible to compile such a volume without utilising the published, and in some cases unpublished, work of others; but an endeavour has been made to acknowledge the source of all borrowed statements, except where disclosure has not been desired. This opportunity is taken to publicly thank those whose kind assistance has contributed so much to the value of this pocket-book.

Finally, as it is intended to keep the volume periodically revised and brought up to date, criticisms and suggestions will always be gladly taken advantage of.

C. G. WARNFORD LOCK.

15, George Street,  
Mansion House, London, E.C.  
*March 1, 1892.*

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## ILLUSTRATIONS.

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# THE MINERS' POCKET-BOOK.

## MOTIVE POWER.

### WORK.

*Work* is measured by product of the resistance and distance through which its point of application is moved. In performance of work by means of mechanism, work done upon weight is equal to work done by power.

*Unit of Work* is the *moment* or effect of 1 lb. through a distance of 1 ft., and it is termed a *foot-pound*.

In France a kilogrammetre is the expression, or the pressure of a kilogramme through a distance of 1 metre = 7·233 foot-pounds.

*Horse-power*.—H.P. is the principal measure of rate at which work is performed. One horse-power is computed to be equivalent to raising of 33,000 lb. 1 ft. high per minute, or 550 lb. per second, or 33,000 foot-pounds of work. It is designated as being Nominal, Indicated, or Actual.

A H.P. in work is estimated at 33,000 lb. raised 1 ft. in a minute but as a horse can exert that force for only 6 hours per day, one work H.P. is equivalent to that of 4·5 horses, at a rate of 3 miles per hour.

*Cheval-vapeur* of France is computed to be equivalent to 75 kilogrammetres of work per second, or 7·233 foot-pounds, or  $75 \times 7·233 = 542·5$  foot-pounds, which is 1·37 per cent. less than American or English value.

1 kilogrammetre = 7·23314 foot-pounds.

1 foot-pound = 0·138253 kilogrammetre.

### MAN POWER. (Haswell.)

Mean effect of power of men working to best practicable advantage, is raising of 70 lb 1 ft. high in a second, for 10 hours per day = 4200 *foot-pounds* per minute.

*Windlass*.—Two men, working at a windlass at right angles to each other, can raise 70 lb. more easily than one man can 30 lb. °

*Labour*.—A man of ordinary strength can exert a force of 30 lb. for 10 hours a day, with a velocity of 2·5 ft. in a second = 4500 lb. raised 1 ft. in a minute = ·2 of work of a horse.



*Man Power—continued.*

A man can travel, without a load, on level ground, during 8·5 hours a day, at rate of 3·7 miles an hour, or 31·45 miles a day. He can carry 111 lb. 11 miles in a day. Daily allowance of water, 1 gal. for all purposes; and he requires 220–240 cub. ft. of fresh air per hour.

A porter going short distances, and returning unloaded, can carry 135 lb. 7 miles a day, or he can transport, in a wheelbarrow, 150 lb. 10 miles in a day.

*Crane.*—The maximum power of a man at a crane, for constant operation, is 15 lb., exclusive of frictional resistance, which, at a velocity of 220 ft. per minute = 3300 foot-pounds, and when exerted for a period of 2·5 minutes is 17·329 foot-pounds per minute.

*Pile-driving.*—In average work at a pile-driver, a labourer, for 10 hours, exerts a force of 16 lb., plus resistance of gearing; and at a velocity of 270 ft. per minute, making one blow every 4 minutes.

*Drawing or Pushing.*—A man drawing a boat in a canal can transport 110,000 lb. for a distance of 7 miles, and produce 156 times the effect of a man weighing 154 lb. and walking 31·25 miles in a day; and he can push on a horizontal plane 20 lb. with a velocity of 2 ft. per second for 10 hours per day.

*Pulley.*—A man can raise by a single pulley 36 lb., with a velocity of ·8 ft. per second, for 10 hours.

*Walking.*—A man can pass over 12·5 times the space horizontally than he can vertically, and by walking in alternate directions upon a platform supported on a fulcrum in its centre, he can, weighing 165 lb., produce an effect of 3,984,000 foot-pounds, for 10 hours per day.

*Pumping.*—A practised labourer can raise, during 10 hours, 1,000,000 lb. water 1 ft. high, with a properly designed and constructed pump.

*Crank.*—A man can exert on the handle of a screw-jack of 11 in. radius for a short period a force of 25 lb., and continuously 15 lb., a net power of 20 lb. Field's tests gave 11·5 lb. as easily attained, 17·3 as difficult, and 27·6 with great difficulty. Walker gives 13 lb. at a velocity of 320 ft. per minute for 8 hours a day.

## MAN'S DAY'S WORK. (D. K. Clark.)

*Labourer.*—Carrying bricks or tiles, net load 106 lb. = 600 lb. 1 mile.

Carrying coal in a mine, net load 95–115 lb. = 342 lb. 1 mile.

Loading coke into a wagon, net load 100 lb. = 270 lb. 1 mile.

Loading a boat with coal, net load 190 lb. = 1230 lb. 1 mile, or 20 cub. yd. of earth in a wagon.

Breaking 1·5 cub. yd. hard stone into 2 in. cubes.

A man can quarry 5–8 tons of rock per day.

Table 1.—EFFECTIVE POWER OF MEN FOR A SHORT PERIOD.

Manner of Application.	Force.
	lb.
Bench-vice or Chisel .. .. .	72
Drawing-knife or Auger .. .. .	100
Hand-plane .. .. .	50
Hand-saw .. .. .	36
Screw-driver, one hand .. .. .	84
Small Screw-driver .. .. .	14
Thumb and Fingers .. .. .	14
Windlass and Pincers .. .. .	60

Smeaton estimates the power of an ordinary labourer at ordinary work as 3762 foot-pounds per minute. In a particular case made by him in the pumping of water 4 ft. high, by good English labourers, their power was equivalent to 3904 foot-pounds per minute.

Table 2.—LABOUR PERFORMED BY A MAN. (Morin.)  
For 10 Hours per Day.

Manner of Application.	Power.	Velocity per Second.	Weight raised. Feet per Minute.	H.P. for Period given.
	lb.	ft.	lb.	No.
Throwing earth with a shovel a height of 5 ft. .. .. .	6	1.33	480	8.7
Wheeling a loaded barrow up an inclined plane, 1 to 12 .. .. .	132	.625	4,950	90
Raising and pitching earth in a shovel 13 ft. horizontally .. .. .	6	2.25	810	14.7
Pushing and drawing alternately in a vertical direction .. .. .	13	2.5	1,950	35.
Transporting weight upon a barrow, and returning unloaded .. .. .	132	1	7,920	144
For 8 Hours per Day.				
Ascending a slight elevation, unloaded .. .. .	143	.5	4,290	62
Walking, and pushing or drawing in a horizontal direction .. .. .	26	2	3,120	45.2
Turning a crank .. .. .	18	2.5	2,790	39
For 7 Hours per Day.				
Walking with a load upon his back .. .. .	88	2.5	13,200	160.5
For 6 Hours per Day.				
Transporting a weight upon his back, and returning unloaded .. .. .	140	1.75	14,700	160.5
Transporting a weight upon his back up a slight elevation, and returning unloaded.. .. .	140	.2	1,680	19
Raising a weight by his hands .. .. .	44	.5	1,320	14.4

### TO COMPUTE NUMBER OF MEN TO PERFORM WORK UPON A PILE DRIVER.

*Rule.*—To product of weight to be raised and radius of crank, add friction of wheel, and divide sum by product of power and radius of wheel.

*Ex.*—How many men are required upon a pile driver, 20 ft. diameter, to raise a weight of 9233·33 lb., crank 9 in. long, weight of wheel and its load estimated at 5000 lb., and friction at ·015?

Weight of a man assumed at 125 lb. Radius of crank ·75 ft.

Effect of a man on a pile driver = 30 lb. at a velocity of 1·3 ft. per second =  $1·3 \times 60 = 78$  ft. per minute.

$9233·33 \times ·75 + 5000 \times ·015 = 7000$  lb. resistance of load and wheel, and  $7000 \div \frac{78}{20 \times 3·1416} \times 10 \times 30 = 7000 =$  load and weight  $\div$  product of power increased by its velocity over load, radius of wheel and power =  $7000 \div 1·241 \times 10 \times 30 = 18·8$  men.

*To compute Effective Power of Men in raising Mineral by Windlass.*

*Rule.*—Multiply the unit of work in turning a handle by the period and the number of men, and divide the result by the depth in ft. multiplied by the lb. in a ton.

*Ex.*—4 men working 8 hours a day drawing mineral from a depth of 25 ft. with a common windlass: how many tons will they raise? *Ans.*

$$\frac{4 \text{ men} \times 8 \text{ hours} \times 60 \text{ minutes per hour} \times 2600 \text{ units of work per minute}}{25 \text{ ft. deep} \times 2240 \text{ lb. in a ton}} = 88\frac{3}{4} \text{ tons.}$$

*To find the Number of Men required to raise a Specific Quantity.*

*Rule.*—Multiply the quantity in tons by the lb. in a ton, by the depth in ft., and divide the result by the number of times, multiplied by the minutes per hour, multiplied by the unit of work.

*Ex.*—To raise 88 $\frac{3}{4}$  tons per day of 8 hours from a depth of 25 ft., how many men required? *Ans.*

$$\frac{88\frac{3}{4} \text{ tons} \times 2240 \text{ lb.} \times 25 \text{ ft.}}{8 \text{ hours} \times 60 \text{ minutes} \times 2600 \text{ units}} = 4.$$

### Excavating. (Fairley.)

A good ordinary labourer can dig and throw out into a barrow, per day of 10 hours:—

- 8–10 cub. yd. common ground.
- 6       "     firm gravel or stiff clay.
- 3–5     "     when so hard as to need picking.

## ANIMAL POWER.

Results of observations upon animal power furnish the following as maximum daily effects:—

1. When effect produced varies from .2 to .33 of that which can be produced without velocity during a brief interval.

2. When the velocity varies from .16 to .25 for a man, and from .08 to .066 for a horse, of the velocity of which they are capable for a brief interval, and not involving any effort.

3. When duration of the daily work varies from .33 to .5 for a brief interval, during which the work can be constantly sustained without prejudice to health of man or animal; the time not extending beyond 18 hours per day, however limited may be the daily task, so long as it involves a constant attendance.

Table 3.—HORSE POWER.  
For 10 Hours per Day. (Morin.)

Manner of Application.	Power.	Velocity per Second.	Weight drawn. Feet per Minute.	H. P. for Period given.
	lb.	ft.	lb.	No.
Drawing a 4-wheeled carriage at a walk ..	154	3	27,720	504
With load upon his back at a walk .. ..	264	3.75	59,400	1080
Transporting a loaded wagon, and returning unloaded at a walk .. .. .	1540	2	184,800	3360
Drawing a loaded wagon at a walk .. ..	1540	3.75	346,500	6300
For 2 Hours per Day				
Upon a revolving platform at a walk			18,000	260.8
For 4.5 Hours per Day.				
Upon a revolving platform at a trot .. ..	66	6.75	26,730	218.7
Drawing an unloaded 4-wheeled carriage at a trot .. .. .	97	7.25	43,195	353.5
Drawing a loaded 4-wheel carriage at a trot ..	770	7.25	334,950	2741

If traction power of a horse, when continuously at a walk, is equal to 120 lb., and grade of road 1 in 30, resistance on a level being one-thirtieth of load, he can draw a load of  $120 \times 30 \div 2 = 1500$  lb.

## Daily Work in France. (Charié-Marsaines.)

Average daily work of a Flemish horse in North of France, where country is flat and loads heavy, is:—

Winter, 21.82 ton-miles per day }  
Summer, 27.82                        } Mean for the year, 25.

Greatest mechanical effect of an ordinary horse is produced in operating a gin or drawing a load on a railroad, when travelling at rate of 2.5 miles per hour, where he can exert a tractive force of 150 lb. for 8 hours per day.

## Tractive Power.

At a speed of 10 miles per hour on a turnpike road, a horse will perform 13 miles per day for 3 years. In ordinary staging, a horse will perform 15 miles per day.

Assuming maximum load that a horse can draw on a gravel road as a standard, he can draw:—

On best broken-stone road .. ..	2 to 3 times.
On a well-made stone pavement ..	3 to 5 "
On a stone trackway .. ..	7 to 8 "
On plank road .. ..	4 to 12 "
On a railway .. ..	18 to 20 "

## Loads.

Assuming load that a horse can draw on a level at 100, he can draw upon inclinations as follows:—

1 in 100	91	1 in 60	85	1 in 30	70
1 " 90	90	1 " 50	82	1 " 25	64
1 " 80	89	1 " 45	80	1 " 20	55
1 " 75	88	1 " 40	77	1 " 15	40
1 " 70	87	1 " 35	74	1 " 10	10

On his back a horse can carry 220–390 lb., or about 27·5 per cent. of his weight.

A draught-horse can draw 1600 lb. 23 miles a day, weight of carriage included.

Ordinary work of a horse may be stated at 22,500 lb. raised 1 ft. in a minute for 8 hours per day.

In a mill, he moves at rate of 3 ft. in a second. Diameter of track should not be less than 25 ft.

A horse weighing 1232 lb. can draw a canal-boat at a speed of 2·5 miles per hour, with a power of 108 lb., 20 miles per day. This is equivalent to a work of 23,760 foot-pounds per minute.

From results of trials upon strength and endurance of horses at Bedford, it was determined that a good horse can draw 1 ton at rate of 2·5 miles per hour, 10–12 hours per day.

Table 4.—Labour a Horse of Average Strength is capable of performing, at Different Velocities, on Canal, Railroad, and Turnpike. (Traction estimated at 83·3 lb.)

Velocity per Hour.	Duration of Work.	Useful Effect, drawn 1 mile.		
		On a Canal.	On a Railroad.	On a Turnpike.
miles.	hours.	tons.	tons.	tons.
2·5	11·5	520	115	14
3	8	243	92	12
4	4·5	102	72	9
5	2·9	52	57	7·2
6	2	30	48	6
7	1·5	19	41	5·1
8	1·125	12·8	36	4·5
10	·75	6·6	28·8	3·6

*Animal Power*—continued.

Actual labour performed by horses is greater, but they are injured by it.

*Tractive Power* of a horse decreases as his speed is increased, and within limits of low speed, or up to 4 miles per hour, it decreases nearly in an inverse ratio.

## Tractive Power. (Wood.)

To find useful work of a horse. *Rule*.—Multiply the number of trips by distance of trip in miles and by weight in tons of each trip = tons drawn 1 mile per diem.

A horse is capable of exerting a force of 120 lb. travelling at the rate of 2-3 miles an hour, and continuing for 10 hours, or for 20 miles per diem. Thus—

$$\frac{3 \text{ miles per hour} \times 5280 \text{ ft. in a mile}}{60 \text{ minutes in an hour}} = 264,$$

$$264 \times 120 \text{ lb. force} = 31,680 \text{ foot-pounds.}$$

*Examples of work to be done*.—(1) Assuming the horse-power at 120 lb., how many cars weighing  $2\frac{1}{4}$  cwt. (252 lb.) each can a horse draw on a tramway rising 1 in 120 and taking the friction at  $\frac{1}{65}$ ? *Ans.*

$$(252 \text{ lb.} \times \frac{1}{120}) 2.1 + (252 \text{ lb.} \times \frac{1}{65}) 3.877 = 5.977,$$

(2) Assuming a car load to weigh 1600 lb., the line rising 1 in 24, and friction at  $\frac{1}{65}$ , what force is necessary to draw it? *Ans.*

$$(1600 \text{ lb.} \times \frac{1}{24}) 66.66 + (1600 \text{ lb.} \times \frac{1}{65}) 24.6 = 91.26 \text{ foot-pounds.}$$

*Mule*. (D. K. Clark.)

*Load on back*, 170-220 lb.; day's work = 6400 lb. 1 mile; 400 lb. at 2.9 miles per hour = 5300 lb. 1 mile, and 330 lb. at 2 miles per hour = 5000 lb. 1 mile.

Upon a revolving platform, at a velocity of 3 ft. per second = 11,880 lb. raised 1 ft. per minute, or 172.2 H.P. for 8 hours per day.

*Ass*.

*Load on back*, 176 lb., carried 19 miles, day's work = 3300 lb. 1 mile.

In Syria an ass carries 450-550 lb. grain.

Upon a revolving platform, at a velocity of 2.75 ft. per second = 5280 lb. raised 1 ft. per minute, or 76.5 H.P. for 8 hours per day.

*Ox.*

An ox, walking at a velocity of 2 ft. in a second (1.36 miles per hour), exerts a power of 154 lb. = 18,480 lb. raised 1 ft. per minute, or 268.8 H.P. for 8 hours per day.

A pair of well-conditioned bullocks in India have performed work = 8000 foot-pounds per minute.

## WIND POWER.

The altitude or head of the atmosphere at uniform density will be the altitude of a column of water 33.95 ft., divided by the specific gravity of the air, 0.0012046, or,

$$\frac{33.95}{0.0012046} = 28,183 \text{ ft.}$$

The velocity due to this head will be—

$V = 8.02 \sqrt{28,183} = 1346.4$  ft. per second, the velocity with which the air will pass into a vacuum.

When air passes into an air of less density, the velocity of its passage is measured by the difference of their density.

$H$  and  $h$  = density of the air in inches of mercury;  $t$  = temperature at the time of passage; and  $V$  = velocity of the wind in ft. per second.

$$V = 1346.4 \sqrt{\frac{H-h}{h}} (1 + 0.00208 t).$$

The force of wind increases as the square of its velocity.

$a$  = area exposed at right angles to the wind in sq. ft.;  $F$  = force of the wind in lb.;  $H$  = horse-power, and  $v$  = velocity of the plane  $a$  in direction of the wind, + when it moves opposite, and - when it moves with the wind.

$$F = 0.002288 a V^2, \quad \text{when } v = 0.$$

$$F = 0.002288 a (V \pm v)^2 \quad H = \frac{a v (V \pm v)^2}{240,384.6}.$$

*Ex.*—A rail-train running E.N.E. 25 miles per hour exposes a surface of 1000 sq. ft. to a pleasant brisk gale N.E. by E. Required the resistance to the train in the direction it moves, and the horse-power lost.

E.N.E. — N.E. by E. = 3 points =  $33^\circ 45'$ ;  $V = 14$  ft. per second, a brisk gale;  $v = 25 \times 1.467 = 36.6$  ft. per second, and  $F = 0.002288 \sin. 233^\circ 45' \times 1000 (14 + \cos. 33^\circ 45' \times 36.6)^2 = 305.1$  lb.

$$205.1 \sim 26.6$$

(Nystrom.)

Table 5.—*Velocity and Force of Wind in lb. per sq. in. (Nystrom.)*

Miles per Hour.	Ft. per Second.	Force per sq. ft., lb.	Common Appellations of the Force of Winds.	Miles per Hour.	Ft. per Second.	Force per sq. ft., lb.	Common Appellations of the Force of Winds.
1	1.47	0.005	{ Hardly perceptible.	18	20.4	1.55	{ Very brisk.
2	2.93	0.020		20	29.34	1.968	
3	4.4	0.044		25	36.67	3.075	
4	5.87	0.079	{ Just perceptible.	30	44.01	4.429	{ High wind.
5	7.33	0.123		35	51.34	6.027	
6	8.8	0.177		40	58.68	7.873	
7	10.25	0.241	{ Gentle pleasant wind.	45	66.01	9.963	{ Very high.
8	11.75	0.315		50	73.35	12.30	
9	13.2	0.400		55	80.7	14.9	
10	14.67	0.492	{ Pleasant brisk gale.	60	88.02	17.71	{ Storm.
12	17.6	0.708		65	95.4	20.85	
14	20.5	0.964		70	102.5	24.1	{ Great storm.
15	22.00	1.107		75	110	27.7	
16	23.45	1.25		80	117.36	31.49	{ Hurricane.
				100	140.66	50	
							Tornado.

## WINDMILLS.

To find the angle at which the sail should be inclined to the plane of revolution at any distance from the centre :—

*Rule.*—Multiply 18 twice by the distance from the centre, divide the product twice by the total radius, and subtract the quotient from 23; the remainder is the inclination in degrees.

*Ex.*—In a windmill 60 ft. diameter, required the inclination of the sail 20 ft. from the centre.

Here 30 ft. is the total radius, and  $\frac{18 \times 20 \times 20}{30 \times 30} = 8$ , which, subtracted from 23, gives  $15^\circ$ , the angle of that point.

In a windmill about 60 ft. diameter, the diameter of the middle point of the arm is 30 ft., the circumference of the circle in which that point revolves is 94 ft. and the number of revolutions made a minute, with a 5 mile an hour wind, is  $\frac{660}{94}$ , about 7. The speed of

the extremities of the arms is 320 ft. a minute, or about 15 miles an hour, or 3 times that of the wind. Under ordinary circumstances the speed of the outer extremities of the arms ranges from 20 to 30 miles an hour. We may assume 30 miles an hour when the wind blows at 10 miles with a pressure of about  $\frac{1}{2}$  lb. on the sq. ft. The total surface of the sails unfurled in a mill 60 ft. diameter, is 1250 sq. ft.; we may suppose half lost by furling, leaving 625 sq. ft. effective. As the surface is set obliquely to the wind, the pressure in the direction of motion would be reduced from  $\frac{1}{2}$  lb. to about  $\frac{1}{3}$  lb. as a mean over the whole of the arms, giving a total pressure



*Windmills—continued.*

in the direction of motion of about 90 lb. The mean velocity of the arms is half that of the extreme, 15 miles an hour, or 1320 ft. a minute. We have therefore 90 lb. moving at 1320 ft. a minute, which is equivalent to a force of  $90 \times 1320 = 118,800$  lb. moving at 1 ft. a minute. Therefore the power of this mill is about  $3\frac{1}{2}$  horse-power. By doubling the diameter of a mill, we quadruple its power, for we quadruple its effective surface.

*Horse-power and Sail-area. (Molesworth.)*

HP = Horse-power.

V = Velocity of wind in ft. per second.

A = Total area of sails in sq. ft.

N = Number of sails.

$$A = \frac{HP \ 1080000}{V^3}.$$

$$HP = \frac{A \ V^3}{1080000}.$$

$$\text{Area of each sail} = \frac{A}{N}.$$

Velocity of tips of sails =  $2.6 \ V$ , nearly.

*Dimensions of Sails. (Molesworth.)*

Length of whip	..	..	..	..	..	..	30	ft.
Breadth of base	..	..	..	..	..	..	12	in.
Depth at base	..	..	..	..	..	..	9	„
Breadth at tip	..	..	..	..	..	..	6	„
Depth	„	..	..	..	..	..	$4\frac{1}{2}$	„

*Rule for Angles of Sails. (Molesworth.)*

A = Angle of the sail with the plane of motion at any part of the sail.

R = Total radius of sail in ft.

D = Distance of any part of the sail from the axis.

$$A = 23^\circ - \frac{18 \ D^2}{R^2}.$$

If the radius of the windmill sails be divided into six equal parts, the angles at each of those parts will be as follows, reckoning from the axis:

Distances from axis..	..	..	..	..	..	tip.
Angle of sail with axis	..	..	..	..	..	85°
Angle of sail with plane of motion	..	..	..	..	..	5

*Windmills*—continued.

Axis of shaft of windmill with horizon =  $8^\circ$  on level ground.

" " " =  $15^\circ$  on high exposed positions.

Breadth of whip at axis =  $\frac{1}{30}$  length of whip.

Depth " " =  $\frac{1}{40}$  "

Breadth of whip at tip =  $\frac{1}{60}$  "

Depth " " =  $\frac{1}{80}$  "

Width of sail " =  $\frac{1}{3}$  "

divided by the whip in the proportion of 5 to 3,  
the narrow portion being nearest to the wind.

Width of sail at axis =  $\frac{1}{6}$  length of whip.

Distance of sail from axis =  $\frac{1}{4}$  "

Cross-bars, 16-18 in. apart.

### WATER.

The natural power contained in a fall of water is equal to the weight of the quantity of water passing over per second, multiplied by the vertical space through which it falls.

Let  $Q$  be the quantity of water which passes through the orifice  $a$  in the time  $t = 1$  second, in cub. ft. of 62.5 lb. each.  $h$  = the vertical space the water falls; then the value or natural effect of the fall is at the orifice  $a$  :

$$P = 62.5 Q h,$$

$$\text{But, } Q = 5.06 a \sqrt{h};$$

$$\text{Then we have } P = 315.5 a h \sqrt{h}.$$

This will be in horse-power,

$$H = 0.573 a h \sqrt{h}, \quad H = 0.1136 Q h,$$

$$h = 1.14 \sqrt[3]{\frac{H^2}{a^2}}, \quad h = \frac{H}{0.1136 Q}.$$

*Ex.*—If a creek passes 18 cub. ft. of water per second, how high must that creek be dammed up to produce an effect of 10 horses?

$$h = \frac{10}{0.1134 \times 18} = 4.9 \text{ ft. (Nystrom.)}$$

### WATER-WHEELS.

*Power.*—The gross power of a water-wheel is found by multiplying the weight  $P$  of the volume furnished by the stream in a second by the height  $H$  of the fall. Dividing this product by 75 kilogram-metres (the work corresponding to 1 H.P.) we get the gross power  $F$  expressed in horse-power,

$$F = \frac{PH}{75}.$$

Table 6.—Comparison of Columns of Water in ft., mercury in in., and pressure in lb. per sq. in. (Nystrom.)

lb. per sq. in.	Water.		Mercury.		Water.		Mercury.		per sq. in.		Mercury.		Water.		per sq. in.	
	ft.	in.	ft.	in.	ft.	in.	ft.	in.	ft.	in.	ft.	in.	ft.	in.	ft.	in.
1	2.311	2.046	1	0.853	1	0.4327	1	0.853	0.4327	1	1.1295	1	1.1295	0.4887	1	0.4887
2	4.622	4.092	2	1.706	2	0.8654	2	1.706	0.8654	2	2.259	2	2.259	0.9775	2	0.9775
3	6.933	6.138	3	2.559	3	1.291	3	2.559	1.291	3	3.3885	3	3.3885	1.4662	3	1.4662
4	9.244	8.184	4	3.413	4	1.7308	4	3.413	1.7308	4	4.5181	4	4.5181	1.9550	4	1.9550
5	11.555	10.230	5	4.266	5	2.1635	5	4.266	2.1635	5	5.6476	5	5.6476	2.4437	5	2.4437
6	13.866	12.227	6	5.120	6	2.5962	6	5.120	2.5962	6	6.7771	6	6.7771	2.9325	6	2.9325
7	16.177	14.322	7	6.1973	7	3.0239	7	6.1973	3.0239	7	7.9066	7	7.9066	3.4212	7	3.4212
8	18.488	16.369	8	7.0826	8	3.4616	8	7.0826	3.4616	8	9.0361	8	9.0361	3.9100	8	3.9100
9	20.800	18.414	9	7.9680	9	3.8042	9	7.9680	3.8042	9	10.165	9	10.165	4.3987	9	4.3987
10	23.111	20.462	10	8.8533	10	4.3273	10	8.8533	4.3273	10	11.295	10	11.295	4.8875	10	4.8875
11	25.422	22.508	11	9.7386	11	4.7600	11	9.7386	4.7600	11	12.424	11	12.424	5.3762	11	5.3762
12	27.733	24.554	12	10.624	12	5.1927	12	10.624	5.1927	12	13.554	12	13.554	5.8650	12	5.8650
13	30.044	26.600	13	11.509	13	5.6255	13	11.509	5.6255	13	14.683	13	14.683	6.3537	13	6.3537
14	32.355	28.646	14	12.394	14	6.0582	14	12.394	6.0582	14	15.813	14	15.813	6.8425	14	6.8425
15	34.666	30.692	15	13.280	15	6.4909	15	13.280	6.4909	15	16.942	15	16.942	7.3312	15	7.3312
16	36.977	32.738	16	14.165	16	6.9236	16	14.165	6.9236	16	18.072	16	18.072	7.8200	16	7.8200
17	39.288	34.784	17	15.050	17	7.3563	17	15.050	7.3563	17	19.201	17	19.201	8.3087	17	8.3087
18	41.599	36.830	18	15.936	18	7.7890	18	15.936	7.7890	18	20.331	18	20.331	8.7975	18	8.7975
19	43.910	38.876	19	16.821	19	8.2217	19	16.821	8.2217	19	21.460	19	21.460	9.2862	19	9.2862
20	46.221	40.922	20	17.706	20	8.6544	20	17.706	8.6544	20	22.590	20	22.590	9.775	20	9.775
21	48.532	42.968	21	18.591	21	9.0871	21	18.591	9.0871	21	23.719	21	23.719	10.264	21	10.264
22	50.843	45.014	22	19.477	22	9.5198	22	19.477	9.5198	22	24.849	22	24.849	10.752	22	10.752
23	53.154	47.060	23	20.362	23	9.9525	23	20.362	9.9525	23	25.978	23	25.978	11.241	23	11.241
24	55.465	49.106	24	21.247	24	10.385	24	21.247	10.385	24	27.108	24	27.108	11.730	24	11.730
25	57.776	51.152	25	22.133	25	10.818	25	22.133	10.818	25	28.237	25	28.237	12.219	25	12.219
26	60.087	53.198	26	23.018	26	11.251	26	23.018	11.251	26	29.367	26	29.367	12.707	26	12.707
27	62.398	55.244	27	23.903	27	11.683	27	23.903	11.683	27	30.496	27	30.496	13.196	27	13.196
28	64.709	57.290	28	24.789	28	12.116	28	24.789	12.116	28	31.626	28	31.626	13.685	28	13.685
29	67.020	59.336	29	25.674	29	12.549	29	25.674	12.549	29	32.755	29	32.755	14.174	29	14.174
30	69.331	61.386	30	26.560	30	12.981	30	26.560	12.981	30	33.885	30	33.885	14.662	30	14.662

Water—continued.

The effective power of the mill depends solely upon the kind of motor adopted: it is the product of the gross power by the useful effect  $K$  of the motor:—

$$\text{Effective power } Fc = K \frac{P H}{75}.$$

It is therefore necessary in each particular case to choose the motor best adapted to the conditions of fall and volume in the stream to be used.

WATER: *Turbines, proportions.* (Cullen.)

Q The quantity of water in cub. ft. per second.

H The height of the waterfall in ft.

P The H.P. of the water at 75 per cent. ..  $= \frac{Q H}{700}.$

$d$  The inner diameter of the wheel .. ..  $= \sqrt[3]{\frac{Q}{H}} + .1.$

N The number of buckets .. ..  $= d \times 3 + 28.$

B The breadth of shrouding .. ..  $= \frac{d \times 55}{N}.$

$s$  The shortest distance between two buckets  $= \frac{B}{4.5}.$

D The external diameter to point of buckets  $= B \times 2 + d.$

A The sectional area in inches between all the buckets .. ..  $= \frac{Q \times 60}{\sqrt{H} \times 2.18}.$

$h$  The height of buckets .. ..  $= \frac{A}{N S}.$

$b$  The breadth of rim for directors .. ..  $= S \times 2.8.$

$r$  The radius for centre of directing channels  $= D \times 3.6.$

$v$  The velocity of inner circumference for low falls .. ..  $= \sqrt{H} \times 4.4.$

V The velocity of inner circumference for high falls .. ..  $= \sqrt[3]{H} \times 8.1.$

R The revolutions of wheel per minute ..  $= \frac{V \times 60}{d \times \frac{2\pi}{7}}.$

U The diameter of turbine shaft in inches ..  $= \sqrt[3]{\frac{P \times 240}{R}}.$

Water—continued.

*Note.*— $A = \frac{Q \times 60}{\sqrt{H} \times 2.18}$  for high falls; but  $A = \frac{Q \times 60}{2.08}$  for falls under 38 ft. Power is gained by extending the shroud about  $\frac{1}{8}$  its breadth past the buckets when the water leaves them.

To find the Power of the Wheel at 75 per cent.—The cub. ft. of water passing through the wheel per minute, multiplied by the height of the waterfall, and divided by 700, will show by the quotient the power of the wheel. Thus, given 100 cub. ft. of water per second on a waterfall of 9 ft., required the proportions for a turbine in accordance with the foregoing rules, to be driven by 50 cub. ft., and 25 occasionally, and at the time of working with these supplies to produce at least 75 per cent. of useful effect:—

$$\sqrt[2]{\frac{Q}{\sqrt[3]{H}}} + .1 = 7.03 \text{ ft., the interior diameter.}$$

$$d \times 3 + 28 = 49, \text{ nearest number of buckets.}$$

$$\frac{d \times 55}{N} = 7.89 \text{ in., breadth of shrouding to point of buckets.}$$

$$\frac{B}{4.5} = 1.753 \text{ in., shortest distance between two buckets.}$$

$$B \times 2 + d = 8.345 \text{ ft., exterior diameter.}$$

$$\frac{Q \times 60}{\sqrt{H} \times 2.08} = 961.53 \text{ in., sectional area of bucket opening.}$$

$$\frac{A}{N S} = 11.175 \text{ in., collected height of buckets.}$$

$$S \times 2.8 = 5.806 \text{ in., breadth of rim of directors.}$$

$$d \times 3.6 = 25.308 \text{ in., radius for directors.}$$

$$\sqrt{H} \times 4.4 = 13.2 \text{ ft., velocity of inner circumference.}$$

$$\frac{v \times 60}{d \times \frac{22}{7}} = 34.54 \text{ revolutions per minute.}$$

$$\frac{77.14 \times 240}{34.54} = 8.12 \text{ in., diameter of shaft.}$$

$$\frac{11.175}{2} = 5.5877 \text{ in. high, first tier of buckets to pass 50 ft.}$$

$$\frac{5.5877}{2} = 2.793 \text{ in. high for second and third tiers, each to pass 25 ft.}$$

Water—continued.

Or, required the number of cub. ft. of water per minute, and all the other dimensions necessary to construct a turbine that will have 34 H.P. on a waterfall of 99 ft. 2 in. :—

$$\frac{34 \times 700}{99 \cdot 16} = 240 \text{ cub. ft. of water per minute, or 4 per second.}$$

$$\sqrt[3]{\frac{Q}{H}} + \cdot 1 = 1 \cdot 029 \text{ ft., the interior diameter.}$$

$$d \times 3 + 28 = 31, \text{ nearest number of buckets.}$$

$$\frac{d \times 55}{N} = 1 \cdot 826 \text{ in., breadth of shrouding.}$$

$$\frac{B}{4 \cdot 5} = \cdot 406 \text{ in., shortest distance between two buckets.}$$

$$B \times 2 + d = 1 \cdot 333 \text{ ft., exterior diameter to point of buckets.}$$

$$\frac{Q \times 60}{\sqrt{H} \times 2 \cdot 18} = 11 \cdot 06 \text{ sq. in., sectional area of openings between buckets.}$$

$$S \times 2 \cdot 8 = \cdot 9288 \text{ in. for rim of directors.}$$

$$\frac{A}{N S} = \cdot 888 \text{ in., height of buckets.}$$

$$d \times 3 \cdot 6 = 3 \cdot 694 \text{ in., radius of directors.}$$

$$\sqrt[3]{H} \times 8 \cdot 1 = 37 \cdot 473 \text{ ft., velocity of inner circumference.}$$

$$\frac{v \times 60}{d \times \frac{\pi}{7}} = 715 \cdot 49 \text{ revolutions per minute.}$$

$$\sqrt[3]{\frac{34 \times 240}{715 \cdot 49}} = 2 \frac{1}{4} \text{ in., diameter of shaft.}$$

In simpler terms, the height of the fall in ft. multiplied by the number of cub. ft. of water per minute, divided by 706, will give the actual brake H.P. The H.P. required multiplied by 706, and divided by the height of the fall in ft., will give the number of cub. ft. of water required per minute. When the available quantity of water and the requisite H.P. are determined, the H.P. multiplied by 706, and divided by the quantity of water in cub. ft. per minute, will give the height of fall in ft. that will be required to produce the H.P. It must be remembered that these rules are based upon 75 per cent. efficiency. But when overshot water-wheels are used, the factor 706 must be altered to 815; or allowing only for 65 per cent., which is as much as can safely be relied upon, after deducting the loss of power in gaining speed by means

*Water—continued.*

of heavy gearing wheels. A good turbine will give 75 to 80 per cent., but in practice nothing more than 75 per cent. should be depended upon.

The old-fashioned water-wheel is, at best, clumsy and cumbrous, but in cases where the fall is less than 20-25 ft., it may be used, provided there is no scarcity of water, and that the cost of transit of so ponderous a machine is not serious; but the danger of accident to the gearing wheels, and the wear of bearings, render it out of place in most instances. It is very largely superseded by turbines, which are so much lighter, and which make so much better use of the water.

*WATER: Turbines.*

Table 7.—*Water required (in cub. ft. per minute) for various powers under various heads.*

	Horse Power.									
	8	10	15	20	30	40	50	60	70	80
3 ft. fall ..	1883	2353	3530							
4 " ..	1412	1765	2648	3530						
6 " ..	941	1176	1765	2353	3530					
8 " ..	706	883	1324	1765	2648	3530				
10 " ..	565	706	1059	1412	2118	2824	3530			
12 " ..	471	588	883	1176	1765	2353	2940	3530		
15 " ..	377	471	706	942	1412	1884	2353	2824	3295	
20 " ..	282	353	530	706	1059	1412	1765	2118	2471	2824
25 " ..	226	282	424	565	847	1130	1412	1694	1977	2260
30 " ..	189	236	353	471	706	942	1176	1412	1648	1883
35 " ..	161	202	303	403	606	806	1010	1212	1412	1612
40 " ..	141	176	265	353	530	706	883	1059	1235	1412
45 " ..	125	157	235	314	471	628	784	941	1098	1255
50 " ..	113	141	212	282	423	565	706	847	988	1130
60 " ..	94	118	176	235	353	471	588	706	824	942
70 " ..	81	101	151	202	303	403	505	606	706	807
80 " ..	71	88	132	176	265	353	441	530	618	706
100 " ..	66	71	106	141	212	282	353	424	494	565

The efficiency is calculated at 75 per cent.

Table 8.—*WATER: Measures.*

1 cub. in. fresh water = .03621 lb.; cub. in.  $\times$  .00360 = gallons.  
 1 " ft. " = 6.24 Eng. gal., or 6.32 U.S. gal., or 62.425 lb., or .557 cwt., or .028 ton. Cub. ft.  $\times$  6.232 = gallons; or  $\times$  62.35 = lb.; or  $\times$  35.92 tons.

*Water—continued.*

1 cub. in. sea water = 64·11 lb.; weight of sea water = 1·027 of fresh water.

1 „ „ ice = 57·3 lb.

1 „ yd. fresh water = 1682·5 lb.

1 Eng. gal. „ = 10 lb., or ·16 cub. ft., or 4·543 litres;  
gallons  $\times$  ·16045 = cub. ft., or  $\times$  277·274  
= cub. in., or  $\times$  ·0044 = tons.

1 lb. „ = ·01607 cub. ft., or ·1 gal.; lb.  $\times$  ·01607  
= cub. ft.

1 cwt. „ = 1·8 cub. ft., or 11·2 gal.

1 ton „ = 35·9 cub. ft., or 224 gal.; tons  $\times$  223·897  
= gallons, or  $\times$  ·02783 = cub. ft.

1 litre „ = 61 cub. in., or ·0353 cub. ft., or ·22 gal.

1 kilo „ = 2·204 lb.

1 cub. metre „ = 1000 kilo., or 1000 litres, or 3531 cub. ft.,  
or 1·308 cub. yd., or 220 gal., or 1 ton  
approximately.

A column „ = a pressure in lb. per sq. in. = half the  
height in ft.; or 1 ft. high = ·434 lb. per  
sq. in.; or 1 lb. per sq. in. = column 2·31  
ft. high.

Rainfall in inches  $\times$  2,323,200 = cub. ft. per sq. mile, or  $\times$  14½ =  
millions of gal. per sq. mile.

P = Pressure in lb. per sq. in.

H = Head of water in ft.

V = Theoretical velocity in ft. per second.

g = Force of gravity.

P = H  $\times$  ·4335.

H = P  $\times$  2·307.

Pressure per sq. ft. = H 62·4.

g = 32·2.      2g = 64·4.       $\sqrt{2g} = 8·025$ .

V =  $\sqrt{2gH} = 8·025 \sqrt{H}$ .

H =  $\frac{V^2}{g} = ·0155 V^2$ .

$\frac{1}{g} = ·0155$ .

#### WATER SUPPLY, calculating. (Stone.)

The water supplied to miners from the races of the Victoria Government is given in three ways:—(a) Through a gauge box, with a pipe of a length equal to two diameters attached. (b) Through a siphon pipe from the channel. (c) Through a sluice-gate opening of known dimensions, and with a stated head kept on it. The modes of calculating the quantity of water passed for these three different methods are as follows. (Stone.)

For calculating the quantity of water passed through a short



*Water*—continued.

pipe of two diameters, with square edges, attached to a box, the following formula may be used :—

$$G = \sqrt{H} \times d^2 \times 13,$$

which, when the diameter is required, may be stated

$$d = \sqrt{\left( \frac{G}{\sqrt{H} \times 13} \right)},$$

and when the head is required,

$$H = \left( \frac{G}{d^2 \times 13} \right)^2,$$

where

$G$  = gal. per minute;

$H$  = head in ft.;

$d$  = diameter in in.

The table on p. 22 is calculated from this rule, and can be extended as follows, this extension being based on one of the laws which govern pipes.

*Rule.*—The discharge of any pipe or series of pipes is proportional to the square root of the head when the length and diameter are constant; therefore, supposing we wanted the discharge through a 4-in. pipe with 4 ft. head, we have by the table for 1 ft. head 208 gal. per minute; therefore, for 4 ft. head the discharge will be

As  $\sqrt{1} : \sqrt{4} :: 208 : 416$  gal. per minute.

*By logarithms.*

$$\text{Log of 4} = 0.6020600$$

$$\begin{array}{r} \text{Log of 1} = 0.0000000 \div 2 \quad 0.3010300 \\ \div 2 = 0.0000000 \text{ log of 208} = 2.3180633 \end{array}$$

$$2.6190933$$

$$\text{Log } \sqrt{1} = 0.0000000$$

$$2.6190933$$

Number corresponding to log 416

2. In calculating the quantity of water passed through a siphon pipe, three things should actually enter into the calculation :—

1st. The head due to velocity of entry.

2nd. The head due to the bend at the top.

3rd. The head due to friction in the pipe.

But as the formula for obtaining the second is very complicated, and as if a large radius is given to the bend it does not make

*Water—continued.*

much difference in the practical result, it may be omitted by the practical miner.

For the first head we shall have, therefore,

$$H = \left( \frac{G}{d^2 \times 13} \right)^2$$

and for the third

$$H = \frac{G^2 \times L}{(3 \times d)^5}.$$

Taking the siphon, we will assume at first that the discharge will be 100 gal. per minute; therefore, neglecting the bend,

*For velocity of entry.*

$$\left( \frac{100}{2.75^2 \times 13} \right)^2 = \text{Head in ft. required. } 0.01034$$

*For friction.*

$$\frac{100^2 \times 22}{(3 \times 2.75)^5} = 5.75640$$

$$\text{Total head} \quad \dots \dots \dots 5.76674$$

*By logarithms.*

Log of 100 =	2.0000000	Log of 2.75 =	0.4393327
Log of 2.75 <sup>2</sup> × 13 =	1.9926088	× 2	2
	0.0073912		0.8786654
× 2	2	× 13	1.1139434
	0.0147824		1.9926088
Number corresponding	0.01034		
Log of 100 =	2.0000000	Log of 2.75 =	0.4393327
× 2	2	” ” 3 =	0.4771213
	4.0000000		0.9164540
× 22	1.3424227	× 5	5
	5.3424227		4.5822700
Log of (3 × 2.75) <sup>5</sup> =	4.5822700		
	0.7601527		
Number corresponding	5.7564		

Water—continued.

Then by the rule before mentioned we have

$$\text{As } \sqrt{5.76674} : \sqrt{10} :: 100 : 131.68 \quad \begin{array}{l} \text{Gal. per minute} \\ \text{required.} \end{array}$$

By logarithms.

$$\begin{array}{rcl} \text{Log of } 10 & = & 1.0000000 \\ \div 2 & & 0.5000000 \\ \times 100 & & 2.0000000 \\ \hline \text{Log of } 5.76674 & = & 0.7609274 \\ & & 2.5000000 \\ & & 0.3804637 \\ \hline \text{For square root } \div 2 & = & 0.3804637 \\ & & 2.1195363 \\ & & \text{Number corresponding to log } 131.68 \end{array}$$

The discharge through the siphon pipe is therefore, neglecting the bend at the summit, nearly 132 gal. per minute if it is wished to include the bend; if the head required for the bend were added, if it is of a *large radius* the difference would be practically nothing, but if of small radius it should be added, as it would reduce the discharge.

3. In calculating the quantity of water passed through a sluice gate with side walls, the formula to be used for obtaining the number of gal. per minute with a given head and opening is

$$G = 8.025 \times \sqrt{H} \times .6 \times A \times 6.23 \times 60,$$

and for the head required on a certain opening to give a certain discharge,

$$H = \left\{ \frac{\left( \frac{G}{6.23 \times 60} \div A \right) \div c}{8.025} \right\}^2.$$

*Ex.*—What will a sluice gate opened 1 ft. and 3 ft. wide discharge with a head to the *centre* of the orifice of 1 ft.? By the formula

$$\begin{array}{rcl} 8.025 \times \sqrt{1} \times .6 \times 3 \times 6.23 \times 60 & = & \text{Gal. per minute.} \\ 8.025 & & 14.4450 \\ 1 & & 6.23 \\ \hline 8.025 & & 433350 \\ .6 & & 288900 \\ \hline 4.8150 & & 866700 \\ 3 & & 89.992350 \\ \hline 14.4450 & & 60 \\ & & 5399.541000 \end{array}$$

or a little over 5399½ gal. per minute.

Water—continued.

If the head had been required to pass 5399·54 gal. per minute through a sluice opening of 1 ft.  $\times$  3 ft.

By formula

$$\left\{ \left( \frac{5399 \cdot 54}{6 \cdot 23 \times 60} \div A \right) \div c \right\}^2 = 1 \text{ ft.}$$

$\begin{array}{r} 6 \cdot 23 \\ \hline 60 \\ \hline 373 \cdot 80 \end{array}$	$\begin{array}{r} 5399 \cdot 54 \\ \hline 37380 \\ \hline 166154 \\ 149520 \\ \hline 166340 \\ 149520 \\ \hline 168200 \\ 149520 \\ \hline 186800 \\ 186900 \end{array}$	$\begin{array}{r} 14 \cdot 445 \\ \hline 3) 14 \cdot 4450 \\ \hline \cdot 6) 4 \cdot 8150 \\ 8 \cdot 025) 8 \cdot 025 \\ \hline 1 \cdot 000 \end{array}$
---	--	--

and the square of 1 is 1; therefore  
the head required is 1 ft.

The water may occasionally be supplied from a *sluice* valve, and then the following formulæ are applicable, assuming that a length of pipe of not more than 2 to 3 diameters is attached to it, for if more pipe is attached, then the friction in the pipe also must be taken into account. Assuming, therefore, that the pipe is not longer than twice or three times the diameter of the *sluice* valve, we may use

$$G = \sqrt{H} \times d^2 \times 10$$

$$H = \left( \frac{G}{d^2 \times 10} \right)^2$$

$$d = \sqrt{\left( \frac{G}{\sqrt{H} \times 10} \right)}.$$

*Ex.*—What is the discharge of a *sluice* valve 4 in. diameter with a head on the *centre* of the valve of 1 ft.? By the formula

$$\begin{aligned} & \sqrt{1} \times 4^2 \times 10 \\ &= 1 \times 16 \times 10 \\ &= 16 \times 10 \\ &= 160 \text{ gal. per minute.} \end{aligned}$$

Water—continued.

If the head is required to discharge 160 gal. per minute, we have

$$\left( \frac{160}{4^2 \times 10} \right)^2 \\ = \frac{160}{160} = 1 \text{ ft.}$$

For diameter we have

$$\sqrt{\left( \frac{160}{\sqrt{1} \times 10} \right)} \\ = \sqrt{\frac{160}{10}} \\ = \sqrt{16} = 4 \text{ in.} \quad (\text{Stone.})$$

Table 9.—WATER SUPPLY :

*Discharges through a Short Pipe of two Diameters coming from a Box, with a Head on the Centre of the Pipe\* of 1 ft. (Stone.)*

Diameter: in.	Discharge : gal. per minute.	Discharge : gal. in 8 hours.	Remarks.
$\frac{1}{2}$	3.25	1,560	The head assumed to give the discharge shown is in all cases 1 ft. in this table.
1	13.00	6,240	
$1\frac{1}{2}$	29.25	14,040	The discharge for any other head may be found by the rule that the discharge is proportional to the square root of the head.
2	52.00	24,960	
$2\frac{1}{2}$	81.25	39,000	A sluice head in Victoria is equal to about 200,000 gal. in 24 hours, therefore a 4-in. pipe in a box of the description given should have a head of 0.668 ft. or $8\frac{2}{3}$ in. over the centre of the pipe to give one "sluice head."
3	117.00	56,160	
$3\frac{1}{2}$	159.25	76,440	The head should be measured to still water— or an addition made for velocity of approach.
4	208.00	99,840	
$4\frac{1}{2}$	263.25	126,360	
5	325.00	156,000	
$5\frac{1}{2}$	393.25	188,760	
6	468.00	224,640	
$6\frac{1}{2}$	549.25	263,640	
7	637.00	305,760	
$7\frac{1}{2}$	731.25	351,000	
8	832.00	399,360	
$8\frac{1}{2}$	939.25	450,840	
9	1053.00	505,440	
$9\frac{1}{2}$	1173.25	563,160	
10	1300.00	624,000	
$10\frac{1}{2}$	1433.25	687,960	
11	1573.00	755,040	
$11\frac{1}{2}$	1719.25	825,240	
12	1872.00	898,560	

\* This pipe is supposed to be horizontal.

WATER: *Miners' "inch."*

The "miners' inch" is an arbitrary measure of the quantity of water which will flow through a given space in a given time, adopted in the early days of American gold-mining, and established by the law of each miners' camp, without any attempt at a universal scale. Thus there are scarcely two localities where the miners' inch has the same signification, the size and shape of the outlet and the manner of discharging the water varying constantly.

The most common way of estimating the "inch" is the amount of water which will pass through an opening 1 in. square in a plank 2 in. thick, with a pressure of 6 in. above the opening or 7 in. over the centre. The thickness of the plank is sometimes 3 in. The lower front end of the discharge is usually chamfered. Raymond says that with an aperture of 1 sq. in. and a pressure of 6 in., the "inch" will equal 94.7 cub. ft. per hour. In other localities the pressure used is 10 in., making 109.1 cub. ft. per hour. The average Californian miners' "inch" he puts at 100 cub. ft. per hour, or 1000 cub. ft. per day of 10 hours. He adds the following table of the standard miners' inch:—

Pressure from Surface to Top or Middle of Orifice.	Miners' inch.	Cub. Ft. (each 6.23 gal.).				Authority.
		Per Second.	Per Minute.	Per Hour.	Per 24 Hours.	
in.						
6	1	0.039	2.34	140	3,360	Hittell.
"	1	0.026	1.57	94.7	2,274	Carpenter.
"	38	1.000	60.00	3600.0	86,400	"
"	1000	264	1580	94,700	2,274,600	"
10	1	0.03	1.8	109.1	2,618	"
6 to 10	1	0.027	1.6	100	2,400	} Standard experimental miners' inch.
"	10	0.27	16	1,000	24,000	
"	100	2.7	166	10,000	240,000	
"	1000	27	1666	100,000	2,400,000	

The Milton Co. reckon a flow through an aperture 12 in. wide and  $12\frac{3}{4}$  in. high, when the water stands 6 in. above the top of the opening, as 200 "inches."

Raymond observes that the usual acceptance of the miners' inch is that given by Hittell, and he quotes the following formula from Haswell for making the calculation:—

$$\frac{2}{3} b \sqrt{2g} (h' \sqrt{h' - h} - h \sqrt{h}) C = V;$$

$b$  being the breadth,  $h'$  the distance from the sill to the surface, and  $h$  the distance from the top of the opening to the surface in feet,

Water—continued.

while C is the coefficient of discharge assumed at 0.750, and V the volume in cub. ft. per second; thus—

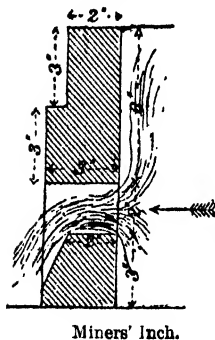
$$\frac{2}{3} \times \frac{1}{12} \sqrt{2g} \left( \frac{7}{12} \sqrt{\frac{7}{12} - \frac{6}{12}} \sqrt{\frac{6}{12}} \right) \times 0.750 = 0.031 \text{ nearly.}$$

He thinks the coefficient of discharge is perhaps a little too high.

Egleston states that the quantity of water which will flow from an opening 1 in. square will be 93 lb. per minute. The opening,

however, is never made 1 in. square, but is always longer or higher, which will necessarily increase the quantity of water which will issue from each sq. in. Thus the quantity of water which is given by a single sq. in. opening will be 93 lb. per minute, and from an opening 1 in.  $\times$  2 in. will be 196½ lb., and with 1 in.  $\times$  100 in. each inch will pass 111 lb. Sometimes the opening is 2 in. high. At North Bloomfield, it is 48 in. long  $\times$  2 in. high, with a pressure of 9 in. above the opening. Each square inch will thus furnish 4252 cub. ft. per 24 hours. At Eureka, the opening is the same, 48 in.  $\times$  2 in., with 6 in. pressure above the top of the opening, so that each square inch will furnish 3240 cub. ft. per 24 hours. . . . The La Grange inch is equal to 2.159 cub. ft. To determine the value of the North Bloomfield

Fig. 1.



“inch,” the water was made to discharge through a 3-in. plank. The bottom of the opening was above the bottom of the tank holding the water (Fig. 1), and was chamfered off 1 in. from the outside, so that the outside opening was 4 in. high. The value of this “inch” is given in the following table, which shows, according to Bowie, the variations in some of the “inches” and their supply:—

Name of Mine.	Height of Opening.	Length of Opening.	Pressure over Centre of Opening.	Quantity discharged by 1 sq. in. per minute.	Quantity discharged in 24 hours.
	in.	in.	in.	cub. ft.	cub. ft.
Smartsville .. ..	4*	†	9	1.76	2534.4
Park Mining Co. ..	..	..	..	1.39	..
North Bloomfield ..	2	50	7	..	..
Eureka .. .. .	2	48	7	..	..

\* The bottom of the aperture is on a level with the bottom of the box.

† An opening 250 in. long  $\times$  4 in. wide will discharge 1000 Smartsville “inches.” The day is usually reckoned as 11 hours.

*Water—continued.*

		H. Smith, 1874.	A. J. Bowle, 1876.
		cub. ft.	cub. ft.
One miner's in. discharges in 1 second	..	0.2624	0.2409
" " 1 minute	..	1.5744	1.4994
" " 1 hour	..	94.4640	89.9640
" " 24 hours	..	2267.1360	2159.1460
Ratio of actual to theoretical discharge	..	61.60 per cent.	59.05 per cent.

Raymond remarks the discrepancies among different companies, thus—

	Height of Aperture.	Pressure.	
Eureka Co. ..	2 in. ..	6 in. ..	{ The amount delivered by them through 20 in. X 2 in. is considered 40 in.
Excelsior ..	— ..	10 " ..	
Scars ..	— ..	10 " ..	{ Measured from centre of orifice.
Mokelumne ..	— ..	4 " ..	
Campo Seco ..	— ..	4 " ..	
Phoenix ..	3 in. ..	4 " ..	Over the orifice.
Gold Hill ..	2 " ..	4 " ..	An inch wide.
Another ..	3 " ..	none ..	An inch wide.

At Smartsville, water is sold with a head of 9 in., with a 14-in. opening 125 in. long, giving 11.8 per cent. for an "inch" more than is usually given. The quantity discharged through an opening 4 in. deep, with a 9-in. head over the middle of the opening, with the coefficient of discharge = 0.0615 is 106.6 cub. ft. per hour, or 1.7767 cub. ft. per minute. A "head of water" is 500 in. daily for 10 hours, and is the quantity required for a first-class hydraulic operation.

*Horse-Power of Miners' inch.*—Theoretical horse-power of the miners' "inch" (Egleston):—

Heads in ft. ..	{ 100	90	80	70	60	50	40
	{ 30	20	15	10	5	3	1
Inches to H.P. ..	{ 3.25	3.61	4.06	4.64	5.41	6.50	8.12
	{ 10.8	16.2	21.6	32.5	65	108	325

With a moderate ditch delivery of 4000 in., or 5 heads at 800 in., the work done may be 1 cub. chain or 10,000 cub. yd. per day, or in a 10 days' run, an acre 1 chain deep or 100,000 cub. yd. Taking an average of 2000 cub. yd. per day of 10 hours, moved by 300 in. of water, 5 days would move a cub. chain or 10,000 cub. yd.; 800 in. at 100 ft. head working 10 hours = 800 10-ft. cubes of water = 800,000 cub. ft., weighing 24,880 tons, without adding the pressure arising from the head employed. This will move through ordinary sluices, at a grade of 8 to 12 in. per box, 3000 cub. yd. of loosened gravel, or 2000 cub. yd. of ordinary uncemented bank gravel, say an average of 2500 cub. yd., weighing 8300 tons or  $\frac{24,880}{8,300} = \frac{3}{1}$  of the weight of the water employed. Reckoned by "inches," the amount of gravel moved = 3 times as many cub. yd. as there are miners' "inches" used. (Raymond.)



WATER: *Measuring Stream.*

(a) The breadth, depth, and velocity of a stream in feet per minute as travelled by a chip, may be estimated by the eye. The sectional area being reduced to sq. ft. and decimals, we have multiple  $\times 60 =$  cub. ft. per hour; divided by 100 = miners' "inches." Or, observe 6 seconds, and the distance  $\times$  area  $\times 6 =$  miners' "inches."

(b) If the channel of the stream has a moderately even outline, measure its depth at regular intervals from shore to shore. Add all these depths together, and divide the sum by the number of soundings. An average depth is thus gained. Calculate then the area of the section by the rule for finding area of a section of a flume with straight sides. Measure the velocity by means of a float, and make the test about half way between the bank and the centre. Multiply the area by the velocity, and the product will be the flow. Of course the test for velocity should be made at the same point where the measurements for depth are made, and a place on the stream should be selected for both where the banks are as nearly parallel as may be, and where the current and flow are the most tranquil. *Ex.*—A stream is 24 ft. broad, and 10 soundings at every 2 ft. on a line from bank to bank give 2, 6, 8, 9, 7, 11, 11, 10, 9, and 2 in. as the depths. The average velocity as determined by float is 4 ft. per second. What is the flow? *Ans.*—The sum of the 10 soundings is 75 in., which gives an average depth of 7.5 in., equal to .625 ft. The area of the section then is 24 multiplied by .625 = 15 sq. ft. The velocity being 4 ft. per second, the flow is equal to 15 multiplied by 4 = 60 ft. per second. If the stream runs over a bottom so irregular that an average depth cannot be gained, or an average velocity measured, there is no recourse but to construct an artificial channel, having no grade, into which it may be turned while measures are made. (Von Wagenen.)

(c) H. T. Turner has lately reviewed the methods used by engineers to estimate the quantity of water (1) when flowing from a state of rest in a pond through an artificial notch, and (2) when flowing in rivers where the stream is greatly disturbed owing to the roughness of the bed. The unit of measurement commonly employed is the cub. ft. discharged per second of time, though for convenience results are often expressed in such derived units as "million gal. per 24 hours."

Notch-gauging, the commonest of all methods of measurement, from the simplicity of the apparatus, observation, and calculation necessary, is applied to ascertaining the flow from a still pond or reservoir, the dimensions of which must be so large relatively to the volume being discharged by the notch, that the water in the neighbourhood of the exit may be in a sensibly statical condition. The form of overfall notch is either rectangular or V-shaped. The plate, usually of metal, which forms the edge of the notch, should be 3-4 in. wide, smooth on the up-stream face, and bevelled away

*Water—continued.*

at the edges on the down-stream face, so as to present a fairly sharp edge to the flowing stream. The weir, in which the plate is fixed vertically, and on the up-stream side, should extend beyond each end of the notch for a distance not less than 3 times the greatest height of water proposed to be passed over the notch sill, and the depth of water below the sill should also not be less than this. Another important feature is that the surface of the pond on the down-stream side of the notch, into which the water discharges, should be sufficiently below the sill to avoid reduction of the atmospheric pressure on the under side of the stream, through the closing in of the ends and exhausting action of the flowing water. The above precautions are essential to accurate notch-gauging, to ensure uniformity of the flow. For its estimation by this method depends mainly upon the results of previous experiment made under such conditions, and it is therefore necessary to observe similarity of conditions in the practical cases to which these results are to be applied.

The rectangular form of notch is used for measuring a fairly constant flow, and the V notch for small and variable flows. In both cases the discharge is the product of the area of the stream in the plane of the notch into its mean velocity past that plane: or  $Q = A V$ .

For the rectangular notch, the ordinary expression for  $Q$ , the rate of discharge in cub. ft. per second, is

$$Q = C l h^{\frac{3}{2}},$$

Where  $l$  is the length of notch;

„  $h$  is the height of still-water surface above the notch-sill;

And  $C$  is a coefficient determined by experiment.

The truth of the expression depends upon a proper value being assigned to  $C$ , to ascertain which many careful experiments have been made. An examination of these shows a striking coincidence in their results when applied to precisely similar conditions, and a general variation of  $C$  as  $\frac{l}{h}$ .

That this coefficient should be some function of  $\frac{l}{h}$ , would appear evident from the consideration, that whilst the influence of the ends of the notch, termed end-contractions, upon the discharge depend in some manner upon  $h$ , their effect relatively to the total discharge must vary inversely as  $l$ .

Although the phenomenon has been noticed both by experimenters and by those who have deduced rules for practical use from their results, it has been customary to obtain from each series of experiments a mean coefficient; and as the investigators have

*Water*—continued.

chiefly confined their experiments to short notches, with consequently but a small range in the values of  $\frac{l}{h}$ , these mean coefficients do not widely differ from one another:—

Name.	Mean value of C.
Dubuat . . . . .	3·38
Eytelwein . . . . .	3·40
Bidone . . . . .	3·32
Poncelet and Lesbros . . . . .	3·23
Brindley and Smeaton . . . . .	3·41
Blackwell . . . . .	3·37

Now, although most of the above means do not differ very much from any of the actual values of C in each series, when the ratio becomes much greater than its average value in the experimental cases, a serious error is introduced by taking C constant. This, in fact, amounts to the diminution of discharge owing to end-contraction, repeated as many times as the length of the notch under consideration is a multiple of that of the experimental notch. It might be inferred that an extension of the experiments to higher values of  $\frac{l}{h}$  would result in higher values of C being obtained; and

Blackwell's experiments on a 10-ft. notch confirm this view. He, however, suggested for practical use the mean value  $C = 3·380$  for a 3-ft. notch, and  $C = 3·570$  for a 10-ft. notch.

Francis avoided the difficulty of introducing a variable coefficient by making the effect of end-contraction a deduction from the full discharge, dependent only upon  $h$ , and specifying that the length of the notch shall be always so great in proportion to the head, that the influence of end-contraction shall not be sensible to a greater distance from either end than to the centre of the flow.

His formula for values of  $h$  between 2 ft. and 0·5 ft. is

$$Q = 3·33 (l - n 0·1 h) h^{\frac{3}{2}},$$

Where  $n$  = the number of end contractions. (In the present case two.)

And provided that the ratio  $\frac{l}{h}$  never becomes less than 3.

His experiments did not extend to this last-mentioned condition, and Turner questions the propriety of applying the formula to such a low value of  $\frac{l}{h}$ . In support of this view, the velocity-curve across an 8 ft. rectangular notch under a head of 0·5 ft. was tried. The velocities were measured with an accurately-rated electric current-meter, whose fan traversed the plane of the notch, clearing

*Water*—continued.

the sill by about  $\frac{1}{4}$  in., and being just covered by the water. The velocities appear generally higher on the left than on the right, attributable to the assistance received by the fan, which was a left-hand one, from the side-flow near the left end of the notch, and the resistance to turning experienced near the right end, owing to the velocity being greater in the lower than in the upper half of the depth. But none the less striking is the diminished velocity near each end of the notch, and it may certainly be taken as extending for a distance of 1.5 ft. into the flow from each end. That is, the total length of notch sensibly affected by end contraction under 0.5 ft. head is 3 ft., or six times the head.

The "coefficients of efflux" determined by Poncelet and Lesbros show that the rate of increase of the coefficient diminishes markedly as the value of  $\frac{l}{h}$  passes from 5 to 8. And because in every similar notch the conditions of flow are similarly affected, this value  $\frac{l}{h} = 6$ , as the least allowable, holds for all notches of like character, no matter what value be assigned to  $h$ . With these restrictions, Francis's formula must be accepted as the most reliable under ordinary practical conditions yet published.

For long notches discharging under small heads, where the value of  $\frac{l}{h}$  is greater than 20, there is, excepting Blackwell's experiments before referred to, no published record of investigation upon the necessary scale to be of use in determining a true expression for discharge. Comparing Blackwell's measurement of the discharge over a 10-ft. notch under a head of 0.16 ft. with that given by the old expression  $Q = C l h^{\frac{3}{2}}$ , where the adopted value of  $C$  is 3.34, the average of the six mean coefficients before noted, it appears that

$Q$  measured by Blackwell = 2.91 cub. ft. per second;

$Q$  by formula  $3.34 l h^{\frac{3}{2}} = 2.34$  „ „

That is, the discharge calculated by the formula falls short of the truth by more than 20 per cent. in this instance. And if the notch were longer, the comparison would be still more unfavourable to the formula.

To meet this difficulty, Turner suggests an expression derived from the following investigation:—Taking the results of Francis's experiments upon a 10-ft. notch, he reduces them to the discharges of a 3-ft. notch under precisely similar conditions of head, and compares these latter quantities with those measured by Blackwell over a 3-ft. notch.

Table 10 shows this comparison.

Table 10.

Francis's Experiments.			Reduction to Discharge over 3-ft. Notch.			Blackwell's Measurement of Discharge (3 ft. Notch.)
Length of Notch.	Head.	Q.	Length of Notch.	Head.	Q.	
ft.	ft.	cub. ft. per second.	ft.	ft.	cub. ft. per second.	cub. ft. per second.
10	1.5	59.30	3	0.45	2.92	2.91
"	1.0	32.60	"	0.30	1.61	1.64
"	0.8	23.40	"	0.24	1.15	1.18
"	0.7	19.20	"	0.21	0.95	0.97
"	0.6	15.30	"	0.18	0.75	0.78
"	0.5	11.70	"	0.15	0.58	0.60

NOTE.—The values of Q in the last column are obtained from the discharge curve drawn through the points determined by Blackwell's experiments.

The reduction is effected by multiplying Francis's method by  $\left(\frac{3}{10}\right)^{\frac{5}{2}}$ , according to the method enunciated by Professor J. Thompson. The close coincidence of the two series of results in the sixth and seventh columns of the Table affords evidence of the accuracy of the gaugings.

But applying the method previously noticed, and reasoning from the lower quantities discharged by a 3-ft. notch to those which a 10-ft. notch would discharge under similar conditions of head, the results obtained are as summarised in Table 11.

Table 11.

Discharge of a 3-ft. Notch, obtained from Equation.		Discharge of a 10-ft. Notch under similar Head.		10-ft. Notch. Blackwell's Measurement under this Head.	10-ft. Notch. Discharge by Formula, D'Aubuisson.	10-ft. Notch. Discharge by Formula, Poncelet.
Head.	Q.	Head.	Q.			
ft.	cub. ft. per second.	ft.	cub. ft. per second.	cub. ft. per second.	cub. ft. per second.	cub. ft. per second.
..	..	0.083	..	1.04	..	..
..	..	0.16	..	2.92	..	..
0.083	0.260	0.277	5.27	..	..	..
0.100	0.340	0.3	6.89	6.76	..	..
0.125	0.468	0.417	9.49	9.36	..	..
0.150	0.607	0.5	12.29	..	12.31	12.04

Column 4 gives values of Q obtained as described. Column 5 gives for comparison the available direct measurements on a 10-ft.

*Water*—continued.

notch (Blackwell's). Columns 6 and 7 give values of  $Q$  under a head of 0.5 ft. according to the ordinary formula, using respectively D'Aubuisson's and Poncelet's values of  $C$  for this ratio of length to height, being the only other available determinations of the coefficients for so high a ratio.

From the value of  $Q$  for any head on the 10-ft. notch (up to  $h = 0.5$  ft.) deduct the value of  $Q$  for the same head on the 3-ft. notch. One-seventh of this difference is the discharge per lineal ft. of the middle portion of the 10-ft. notch not affected sensibly by end contraction. Thus  $Q$  per lineal ft. of notch unaffected by end contraction is

$$\left( \frac{33.15 - 9.13}{7} \right) h^{\frac{10}{7}} = 3.43 h^{\frac{10}{7}}$$

However the length of notch be increased for the low heads under consideration (i. e.  $h$  less than 0.5 ft.), and when  $l$  is not less than 3 ft.

$$Q = (l - 3) 3.43 h^{\frac{10}{7}} \times 9.13 h^{\frac{10}{7}},$$

cub. ft. discharged per second,

$$- 3.43 (l - 0.34) h^{\frac{10}{7}}.$$

As evidence of the accuracy of the formula, Turner submits the results of three experiments on an 8-ft. notch in Table 12:—

Table 12.

Head.	Measured Discharge over an 8-ft. Overfall Notch.	By Formula. $Q = 3.43 (l - 0.34) h^{\frac{10}{7}}$ .	By Formula. $Q = 3.34 l h^{\frac{3}{2}}$ .
ft.	cub. ft. per second.	cub. ft. per second.	cub. ft. per second.
0.563	11.33	11.56	11.29
0.5	9.87	9.88	9.43
0.354	6.09	5.96	5.64

Column 4 shows the deficiency caused by the use of the mean coefficient in this case of high values of  $\frac{l}{h}$ .

In lower values of  $h$ , error in defect, through the use of a mean coefficient, increasing with the value of  $\frac{l}{h}$ , is noticeable, and cannot be far short of 20 per cent. when  $h = 0.2$  ft.

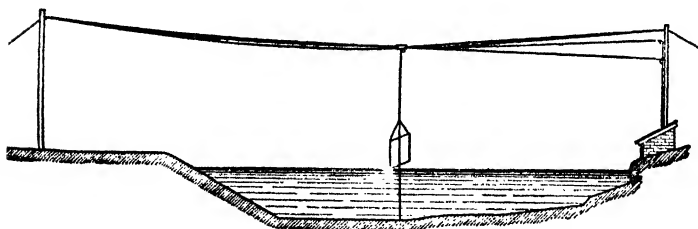
The quantities discharged were computed from velocity observations made in a straight and uniform brick channel that carries the water from the Lower Rivington reservoir to the still pond

*Water*—continued.

above the notch. An accurately-rated electric current-meter was used, and each experiment comprised a series of twenty velocity measurements in a cross section of about 13 sq. ft. The readings of the meter were taken twice at each point, and before commencing a series it was ascertained that the condition of the channel and pond was permanent. Gauging with the V notch is not attended with the difficulties in computation attached to the rectangular form, and an accurate expression for the discharge is a matter of ordinary hydraulics.

As an example of the most modern method of accurate river-gauging, Turner describes the operation of gauging the flow of the River Severn, in connection with the Liverpool Water Act, for obtaining a new supply from the River Vyrnwy. The site selected was at a point about 1 mile above the Diglis Weir at Worcester, on a straight reach  $\frac{1}{2}$  mile in length. The river is here 180 ft. wide, and when bank-full is about 25 ft. deep in the middle. The section having been accurately levelled, two staffs were fixed on opposite sides of the river with their zero points at the level of the lowest dry-weather flow, and the discharges corresponding with different readings of these staff-gauges were computed from velocity measurements made at each foot of depth below the water surface, past verticals 10 or 20 ft. apart in the cross section. These measurements were made with two of Deacon's electric current-meters previously rated. Fig. 2 is a sketch of the apparatus specially

Fig. 2.



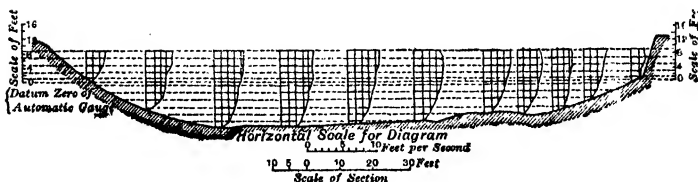
River Severn. Section of River showing Gauging Tackle.

constructed for directing the meters to any position in the river section. It consists of two upright poles, 50 ft. in height, placed 240 ft. apart on opposite sides of the river. Between these poles is stretched tightly a No. 12 steel wire, upon which traverses a small carriage mounted on two 3-in. pulleys; the carriage is moved forwards or backwards by an endless wire passing round pulleys at the head of each pole, and wound upon rollers at the foot of the pole on the east bank. From this carriage is suspended, firmly

*Water—continued.*

attached to it by means of jaws, a T-shaped frame of  $\frac{1}{2}$ -in. iron piping pointing up and down stream, and carrying, at each extremity of the T-piece, pulleys, over which pass two other wires attached to a lower bar of the same length as the T-piece. These wires are led over a pulley in the carriage to a roller similar to those previously mentioned. The diameters of the rollers are suitably arranged for paying out standard lengths of wire for a given number of turns. The lower bar carries on its up-stream end a socket into which is fixed a short upright rod, and upon this the current-meters are securely clamped, and by means of the above gear they can be brought into any position in the cross section. A fourth wire passes over a pulley in the carriage, down the inside of the stem of the T, and through the lower bar, and is attached to a cast-iron anchor-plate weighing 70 lb., which rests on the bed of the river. It is armed on the under side with six 3-in. spikes, and its use is to keep the T-frame and lower bar vertically in position during an observation. By means of the last-mentioned wire it is raised when the meters have to be moved on to a fresh vertical. The insulated wires are carried from the meters over the head of the T-frame to a shed where the rollers and electrical apparatus are placed, and in which the operators stand. The method of computing the discharge of the river corresponding with any staff-reading is as follows:—The observed velocities past each vertical are plotted to a large scale on a diagram, so as to form velocity-curves at each point whose areas represent the discharges past the respective verticals. The integration of a complete series of such discharges gives the total corresponding rate of discharge. Fig. 3 shows a diagram of one complete series of observations. Both staff-

Fig. 3.



River Severn. Velocity Observations.

gauges are read regularly throughout each operation, and the mean water-level is carefully determined. The results of observations are plotted to a curve. From this curve is constructed a discharge-scale, giving the rate, in million gallons per day, corresponding with the staff-gauge reading used for computing the



*Water*—continued.

daily flow of the river from the diagrams of an automatic gauge. These are drawn by a pen whose zero coincides with that of the staff-gauges before mentioned. (H. T. Turner.)

(d) Cullen gives the following rules for ascertaining the velocity of water in rivers:—Select a portion of the watercourse where the direction of the running water is as straight as possible. Measure some convenient distance along the stream, say 100 ft.; at the extremities of this length, and at right angles across the stream, fix two straight cords; then get a few floats of hard wood, or well-corked bottles (they should be so weighty that when placed in the water they would not project over it as to be materially affected by the wind). After having these preparations made, the floats are dropped lightly into the current at a little distance above the upper cord, then note the time by a stop-watch that the float takes to pass over the distance between the two cords. This experiment should be repeated several times with floats both in the middle and near the sides of the stream, the arithmetic mean is then taken for the surface velocity of each experiment. Having by these means found the several spaces run over in a given time, the mean proportion of all these trials is taken for the surface velocity of the water. Four-fifths of the surface velocity is a good approximation to take for the mean velocity of the stream, or the velocity it would have supposing all the particles of the stream to have moved in every part of its channel with one uniform motion. If this velocity be multiplied by the breadth and depth of the mass of flowing water, the product will be the number of cub. ft. which passed from one cord to the other during the time of observation. This may be adapted to any other proportion of time. *Ex.*—Required the quantity of water discharged in cub. ft. per minute, in a channel 8 ft. broad, and water 2 ft. deep, supposing the measured distance between two cords placed across the channel to be 100 ft.; and after making 5 different experiments on the time which floats took to pass from one cord to the other, it was found to be as follows:—At the first trial it took  $11\frac{1}{2}$  seconds; at the second, 12; at the third, 13; at the fourth, 10; and at the fifth,  $13\frac{1}{2}$ . Then  $11\frac{1}{2} + 12 + 13 + 10 + 13\frac{1}{2} = 60$ ; and  $\frac{60}{5} = 12$  seconds for the mean

time that the floats took to pass the 100 ft.,  $\frac{4}{5}$  this distance = 80 ft.

for the mean velocity of the stream in 12 seconds;  $12:60::80:400$  ft. for the velocity of the stream per minute;  $400 \times 8 \times 2 = 6400$  cub. ft., the required answer.

To abridge calculation, Table 13 shows mean velocities corresponding to surface velocities from 120 to 800 ft. per minute at one glance.

Table 13.—*Surface and Mean Velocities of Water in ft. per minute.*

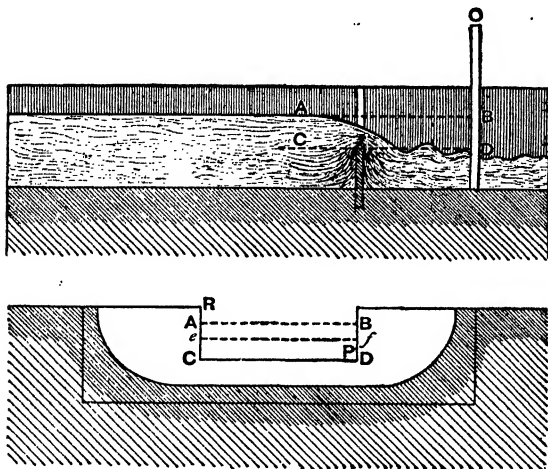
Surface Velocity.	Mean Velocity.	Surface Velocity.	Mean Velocity.	Surface Velocity.	Mean Velocity.
120	98·00	212·5	182·40	310	273·1
122·5	100·25	215	184·75	315	277·8
125	102·50	217·5	187·05	320	282·5
127·5	104·75	220	189·35	325	287·2
130	107·00	222·5	191·65	330	291·9
132·5	109·25	225	193·95	335	296·6
135	111·55	227·5	196·30	340	301·2
137·5	113·80	230	198·60	345	305·9
140	116·05	232·5	200·90	350	310·6
142·5	118·30	235	203·25	355	315·3
145	120·60	237·5	205·55	360	320·1
147·5	122·85	240	207·85	365	324·8
150	125·15	242·5	210·20	370	329·5
152·5	127·40	245	212·50	375	334·2
155	129·65	247·5	214·85	380	338·9
157·5	131·95	250	217·15	385	343·6
160	134·20	252·5	219·50	390	348·3
162·5	136·50	255	221·80	395	353·0
165	138·80	257·5	224·15	400	357·8
167·5	141·05	260	226·45	405	362·5
170	143·35	262·5	228·80	410	367·2
172·5	145·65	265	231·10	415	371·9
175	147·95	267·5	233·45	420	376·7
177·5	150·20	270	235·75	425	381·4
180	152·50	272·5	238·10	430	386·1
182·5	154·80	275	240·45	435	390·8
185	157·10	277·5	242·75	440	395·6
187·5	159·40	280	245·10	445	400·3
190	161·70	282·5	247·45	450	405·1
192·5	164·00	285	249·75	500	452·5
195	166·30	287·5	252·10	550	500·0
197·5	168·60	290	254·45	600	547·7
200	170·90	292·5	256·75	650	595·5
202·5	173·20	295	259·10	700	643·3
205	175·50	297·5	261·45	750	691·2
207·5	177·80	300	263·75	800	739·2
210	180·10	305	268·40		

(c) More Correct Method.—Look for some convenient portion of the watercourse, where the water is running slowly. In a perpendicular position and at right angles across it, fix an overfall of boards, as is shown in Figs. 4, 5, in such a manner that the water shall accumulate behind it so high that it will flow over the horizontal edge of the rectangular opening R P, and afterwards have ample room for its free escape. The edges of the boards forming the opening should be sharp and smooth, and all leaks round the bottom and sides carefully closed with clay, in order that the whole water may pass through the opening *e f*. The cross section of the water should be at least 8 times the length of notch *e f*, and the depth of the water under C D should be 4 times

*Water—continued.*

the depth of B D. At a distance below the overfall a rod O is fixed vertically, having a mark D at the exact level of the edge of the notch C D. When the water has risen to its greatest height, and its surface observed to be horizontal, the depth from the surface of the water A B to the mark on the rod D is noted in inches in column 1 of Table 14. Then on the same line with that number in

Figs. 4, 5.



! Overfall for Measuring Stream.

column 3 of Table 14 is a number which, if multiplied by  $ef$  the width of the notch in inches, will give the quantity of water in cub. ft. per minute, providing the width of the notch is less than 7 times the depth B D, but when the width  $ef$  is more than 7 times the depth that D is below B, column 2 is taken; when  $ef$  is equal to B D the quantity of water discharged through the notch will be as much less as the quantity contained in column 3 of Table 14 is to that contained in 2.

*Ex. 1.*—When  $ef$  and B D are each 24 in., column 3 in Table 14 gives a discharge of 47·515 cub. ft. of water in one minute, and column 2 gives 50·465. The difference of these two numbers is 2·95. This difference subtracted from 47·515, the remainder will be 44·55 cub. ft. of water discharged per minute by every inch in width of the notch when B D and  $ef$  are of the dimensions now given.

Table 14.—Quantity of Water discharged over Weirs or Notches in cub. ft. per minute by every inch of their length. Column 2 is calculated from Smeaton's experiments; column 3 according to DU BUAT'S.

1.	2.	3.	1.	2.	3.
Depth falling over.	Discharge per minute over Weir.	Discharge per minute over Notch.	Depth falling over.	Discharge per minute over Weir.	Discharge per minute over Notch.
in.	cub. ft.	cub. ft.	in.	cub. ft.	cub. ft.
0.25	.053	.050	10.75	15.128	14.244
0.5	.115	.113	11	15.659	14.743
0.75	.278	.262	11.25	16.196	15.249
1	.429	.404	11.5	16.739	15.760
1.25	.599	.565	11.75	17.296	16.277
1.5	.788	.742	12	17.926	16.799
1.75	.993	.936	12.5	18.969	17.860
2	1.214	1.143	13	20.119	18.942
2.25	1.448	1.364	13.5	21.299	20.045
2.5	1.697	1.597	14	22.484	21.169
2.75	1.957	1.843	14.5	23.699	22.313
3	2.230	2.110	15	24.935	23.477
3.25	2.515	2.368	15.5	26.192	24.661
3.5	2.810	2.646	16	27.470	25.864
3.75	3.117	2.935	16.5	28.768	27.085
4	3.434	3.233	17	30.085	28.328
4.25	3.761	3.541	17.5	31.422	29.585
4.5	4.097	3.858	18	32.778	30.862
4.75	4.443	4.184	18.5	34.153	32.156
5	4.799	4.518	19	35.547	33.469
5.25	5.163	4.861	19.5	36.960	34.799
5.5	5.536	5.213	20	38.390	36.146
5.75	5.918	5.572	20.5	39.839	37.509
6	6.308	5.939	21	41.305	38.890
6.25	6.706	6.314	21.5	42.789	40.287
6.5	7.113	6.697	22	44.291	41.701
6.75	7.527	7.087	22.5	45.809	43.131
7	7.949	7.484	23	47.344	44.576
7.25	8.379	7.889	23.5	48.897	46.038
7.5	8.816	8.300	24	50.465	47.515
7.75	9.260	8.719	25	53.652	50.517
8	9.712	9.144	26	56.903	53.576
8.25	10.171	9.576	27	60.218	56.697
8.5	10.636	10.015	28	63.594	59.875
8.75	11.101	10.460	29	67.050	63.111
9	11.589	10.911	30	70.528	66.404
9.25	12.075	11.369	31	74.083	69.752
9.5	12.568	11.833	32	77.698	73.154
9.75	13.067	12.303	33	81.367	76.602
10	13.573	12.779	34	85.094	80.118
10.25	14.085	13.262	35	88.875	83.678
10.5	14.604	13.750	36	92.711	87.290

When using Table 14 the breadth of notch must not exceed 6 times the depth of the water running over it.

Table 15 is used for common weirs with straight approach, but when the approach is rough, a medium between these quantities is taken.

— <i>Vel.</i>			<i>dim.</i> <i>Sh.</i>			<i>ead.</i>		
Head of Water from the Surface to Centre of Sluice Opening.	Velocity of Water when the Head of Pressure is less than 6 times the Depth of the Sluice Opening.	Velocity of Water when the Head of Pressure is more than 6 times the Depth of the Sluice Opening.	Head of Water from the Surface to Centre of Sluice Opening.	Velocity of Water when the Head of Pressure is less than 6 times the Depth of the Sluice Opening.	Velocity of Water when the Head of Pressure is more than 6 times the Depth of the Sluice Opening.	Head of Water from the Surface to Centre of Sluice Opening.	Velocity of Water when the Head of Pressure is less than 6 times the Depth of the Sluice Opening.	Velocity of Water when the Head of Pressure is more than 6 times the Depth of the Sluice Opening.
ft. in.			ft. in.			ft. in.		
0 4	3.09	2.956	1 2	5.77	5.530	2 10½	9.06	8.681
0 4½	3.18	3.047	1 2½	5.83	5.618	3 0	9.25	8.763
0 5	3.27	3.135	1 3	5.98	5.716	3 1½	9.45	9.051
0 5½	3.45	3.305	1 3½	6.07	5.819	3 3	9.55	9.133
0 6	3.62	3.468	1 4	6.17	5.911	3 4½	9.82	9.305
0 6½	3.78	3.621	1 4½	6.27	6.004	3 6	9.99	9.579
0 7	3.93	3.868	1 5	6.36	6.094	3 7½	10.18	9.749
0 7½	4.08	3.910	1 5½	6.45	6.183	3 9	10.35	9.915
0 8	4.23	4.047	1 6	6.54	6.271	3 10½	10.52	10.079
0 8½	4.36	4.181	1 7	6.72	6.443	4 0	10.70	10.209
0 9	4.50	4.309	1 8	6.90	6.610	4 2	10.91	10.451
0 9½	4.63	4.436	1 9	7.07	6.773	4 4	11.13	10.658
0 10	4.75	4.555	1 10	7.24	6.933	4 6	11.34	10.861
0 10½	4.88	4.674	1 11	7.40	7.088	4 8	11.55	11.060
0 11	5.00	4.789	2 0	7.56	7.241	4 10	11.75	11.256
0 11½	5.12	4.902	2 1½	7.80	7.464	5 0	11.95	11.449
1 0	5.23	5.012	2 3	8.02	7.680	5 3	12.25	11.737
1 0½	5.34	5.120	2 4½	8.24	7.891	5 6	12.53	12.007
1 1	5.45	5.223	2 6	8.45	8.095	5 9	12.82	12.278
1 1½	5.56	5.327	2 7½	8.66	8.295	6 0	13.09	12.488
1 1½	5.67	5.431	2 9	8.96	8.491			

*Water—continued.*

*Ex. 2.*—Required the quantity of water in cub. ft. per minute discharged through a notch 60 in. long and 9 in. deep from B to D. In that case, as the distance from B to D is less than 7 times the distance from *e* to *f*, we take column 3 to find the quantity. Then opposite, in column 1, the corresponding number is 10·91, and this multiplied by 60, the length, gives 654·6 cub. ft. per minute.

*Ex. 3.*—Let B D the depth be 12 in., and *e f* the length 100 in., to find the number of cub. ft. that would pass through this opening per minute. In this case column 2 is taken. Opposite 12 in. deep is 17·926, which multiplied by the length, 100 in., will give 1700·926 cub. ft. per minute. Column 2 is in accordance with Smeaton's experiments, which were made on water running in parallel channels, and flowing over the edge of a plank placed horizontally and at right angles across the entire breadth of a weir or stream, offering no lateral obstruction to the water flowing over it. But column 3 was calculated for a waste board, having a notch cut in it narrower than the channel in which it was placed, in consequence of which the water, in meeting the ends of the notch, and afterwards turning into the opening, contracts its passage, and causes a less discharge in a given time: the breadth of the notch and depth of the water being the same in both cases.

If the quantity of water that passes through a sluice opening be required, see the velocity of the water in Table 15 corresponding to the given head of water, which, if multiplied by the area of the sluice opening, will be the number of cub. ft. passing per second.

#### WATER: *Flumes and Ditches.*

*Wet Perimeter.*—If a flume or ditch is 20 in. wide, 6 in. deep, and full of water, its wet perimeter is  $20 + 6 + 6 = 32$  in. If of the same dimensions, but only containing 3 in. of water, the wet perimeter is  $20 + 3 + 3 = 26$  in. The same flume again, if empty, has no wet perimeter at all. In other words, the wet perimeter of a water-channel is the length of so much of its base and sides as is wetted by the water.

*To find the Area of a Section of a Flume with Straight Sides.*—Multiply the width of bottom (in inches) by the height of sides (in inches), the product will be the area in sq. in., which, divided by 144, gives the area in sq. ft. *Ex.*—What is the area of a section of a flume 20 in. wide and 15 in. high? *Ans.*—20 multiplied by 15 = 300, which divided by 144 = 2·08 sq. ft.

*To find the Area of the Section of a Ditch with Sloping Sides.*—Add together the width at top and bottom (in inches), multiply this sum by the depth (in inches), and divide the result by 2. The quotient, divided by 144, will be the area in sq. ft. *Ex.*—What is the area of the cross-section of a ditch 60 in. wide at the top, 36 in. at the bottom, and 12 in. deep? *Ans.*— $60 + 36 = 96$ , which multiplied

*Water*—continued.

by  $12 = 1152$ , and this divided by  $2 = 576$  sq. in., which divided by  $144 = 4$  sq. ft.

*To find the Area of the Cross-section of a Ditch whose Sides slope to a Point at the Bottom.*—Multiply the width (in inches) by half the depth (in inches), and divide the product by 144. The result is the area in sq. in. *Ex.*—What is the area of a pointed ditch 60 in. wide and 18 in. deep in the centre? *Ans.*—60 multiplied by 9 (half the depth) = 540 sq. in., which divided by 144 = 3.75 sq. ft. (Von Wagenen.)

**WATER:** *To determine the Capacity of Ditches, Canals, or Flumes.*  
(Hendy.)

In cases where the sectional areas are equal, but of different forms:

The simplest form of construction of a ditch or canal is that in which the width of the bottom is made equal to one of the sides, and in which the base to the perpendicular of the side slope is as 3 : 4; and this form has been adopted as the standard where the topography of the ground will admit.

The relative carrying capacity for trapezoidal form, base : depth of slope : : 3 : 4; bottom width : depth : : 5 : 4. Coefficient of capacity = 1000.

Trapezoidal form, base : depth of slope : : 1 : 1; bottom width = depth, .994.

Flume, 2 : 1, .961; semi-hexagonal, 1.008; square, 925; semi-circular, 1.056.

The fall being 8 ft. to the mile, and the sectional area of a square flume being 11.52 sq. ft., what will be its carrying capacity per second?

In Table 16, in column headed "fall per mile," find the given fall 8 ft., and opposite in column headed (6'-6"-3'-2'-4) or a sectional area of 11.52 sq. ft. will be found 25.60 cub. ft., which, multiplied by the coefficient for a square given above, gives  $25.60 \times .925 = 23.68$  cub. ft., or  $\times .50 = 1184$  miners' inches.

The tables given to determine the flow of water through ditches, canals, or flumes have been computed upon the assumption that they are generally smooth and straight.

**WATER:** *To determine Proportions of Channels.* (Thiré.)

Where artificial channels or flumes have to be constructed for conveying water for power purposes, there is often considerable uncertainty in determining the relative proportions and dimensions of the area and inclination of the channel, and the quantity and velocity of the water.

Table 16.—WATER: Flow in Open Channels—Base to Perpendicular of the Side Slopes being as 3:4. (Hendy.)

Fall per Mile.	Fall per Rod.	T 2.2 ft. B 1.0 ft. D 0.8 ft. Section 1.28 sq. ft.	T 3.3 ft. B 1.5 ft. D 1.2 ft. Section 2.88 sq. ft.	T 4.4 ft. B 2.0 ft. D 1.6 ft. Section 5.12 sq. ft.	T 5.5 ft. B 2.5 ft. D 2.0 ft. Section 8.0 sq. ft.	T 6.6 ft. B 3.0 ft. D 2.4 ft. Section 11.52 sq. ft.	T 7.7 ft. B 3.5 ft. D 2.8 ft. Section 15.68 sq. ft.	T 8.8 ft. B 4.0 ft. D 3.2 ft. Section 20.48 sq. ft.
ft.	in.	cu. ft.	cu. ft.	cu. ft.	cu. ft.	cu. ft.	cu. ft.	cu. ft.
1	.0375	0.45	1.33	2.67	5.57	9.05	13.46	20.26
2	.0750	0.63	1.88	3.87	7.88	12.80	19.04	28.64
3	.1125	0.77	2.30	4.74	9.65	15.67	23.32	35.08
4	.1500	0.89	2.65	5.47	11.14	18.52	26.93	40.51
5	.1875	1.00	2.97	6.12	12.46	20.24	30.11	45.30
6	.2250	1.01	3.25	6.70	13.65	22.17	32.98	49.62
7	.2625	1.18	3.42	7.24	14.74	23.94	35.63	53.58
8	.3000	1.26	3.75	7.73	15.75	25.60	38.08	57.29
9	.3375	1.34	3.98	8.21	16.71	27.15	40.39	60.76
10	.3750	1.41	4.19	8.65	17.61	28.62	42.57	64.05
11	.4125	1.48	4.40	9.07	18.47	30.02	44.65	67.18
12	.4500	1.54	4.60	9.48	19.30	31.35	46.64	70.65
13	.4875	1.61	4.78	9.86	20.08	32.63	48.54	73.03
14	.5250	1.67	4.96	10.24	20.84	33.87	50.38	75.79
15	.5625	1.73	5.14	10.60	21.57	35.05	52.14	78.44
16	.6000	1.78	5.31	10.94	22.27	36.20	53.86	81.02
17	.6375	1.84	5.47	11.28	22.96	37.31	55.51	83.51
18	.6750	1.89	5.63	11.60	23.63	38.39	57.11	85.93
19	.7125	1.94	5.78	11.92	24.28	39.44	58.58	88.29
20	.7500	1.99	5.93	12.23	24.91	40.47	60.21	90.58
21	.7875	2.04	6.08	12.54	25.53	41.47	61.70	92.82
22	.8250	2.09	6.22	12.83	26.12	42.45	63.15	95.00
23	.8625	2.14	6.36	13.12	26.71	43.40	64.57	97.15
24	.9000	2.18	6.50	13.40	27.29	44.34	65.95	99.23
25	.9375	2.23	6.63	13.68	27.98	45.24	67.32	101.28

T signifies top width; B, bottom width; D, depth.



Table 16—continued.

Fall per Mile.	Fall per Rod.	T 9-9 ft. B 4-5 ft. D 3-6 ft. Section 25-92 sq. ft.	T 11 ft. B 5 ft. D 4 ft. Section 32 sq. ft.	T 13-2 ft. B 6-0 ft. D 4-8 ft. Section 46-09 sq. ft.	T 16-4 ft. B 7-0 ft. D 5-6 ft. Section 62-72 sq. ft.	T 17-6 ft. B 8-0 ft. D 6-4 ft. Section 81-92 sq. ft.	T 19-8 ft. B 9-0 ft. D 7-2 ft. Section 103-63 sq. ft.	T 22 ft. B 10 ft. D 8 ft. Section 128 sq. ft.
1	.0375	in. 28-04	37-1	58-4	96-5	138-3	189-2	261-2
2	.0750	39-67	52-4	82-7	136-4	193-7	267-6	369-4
3	.1125	43-59	64-2	101-4	167-1	239-6	327-7	451-3
4	.1500	59-10	74-1	117-1	192-9	276-7	378-4	522-3
5	.1875	62-71	82-9	130-9	215-7	309-3	423-1	584-0
6	.2250	68-70	90-8	143-4	238-3	338-8	463-5	639-8
7	.2625	74-19	98-1	154-8	255-3	368-0	500-5	691-0
8	.3000	79-53	104-8	165-5	272-9	391-2	535-1	738-7
9	.3375	84-14	111-1	175-6	289-4	415-0	567-6	783-5
10	.3750	88-39	117-1	185-1	305-0	437-4	598-2	825-9
11	.4125	93-02	122-9	194-1	319-9	458-7	613-2	866-2
12	.4500	97-15	128-4	202-8	334-2	479-1	655-4	925-6
13	.4875	101-13	133-6	211-1	347-8	498-7	682-1	941-7
14	.5250	104-94	138-7	219-0	360-9	517-5	707-8	977-2
15	.5625	108-63	143-5	226-6	373-6	535-7	732-8	1011-5
16	.6000	112-18	148-2	234-1	383-9	553-3	756-7	1044-7
17	.6375	115-64	152-4	241-3	397-8	570-3	780-1	1076-9
18	.6750	119-99	157-2	248-3	409-3	586-9	802-7	1108-1
19	.7125	123-26	161-5	255-1	420-5	601-5	824-8	1138-4
20	.7500	126-43	165-7	261-7	431-4	618-5	846-1	1168-0
21	.7875	129-53	169-8	268-2	442-0	633-9	867-0	1196-8
22	.8250	131-55	173-8	274-5	452-5	648-8	887-4	1225-0
23	.8625	134-51	177-7	280-7	462-9	663-4	907-7	1252-6
24	.9000	137-40	181-5	286-7	473-6	677-7	926-9	1279-5
25	.9375	140-24	185-3	292-6	482-3	691-6	946-0	1306-0

T signifies top width; B, bottom width; D, depth.

Table 17.—WATER: Flow in Open Channels—Base to Perpendicular of the Side Slopes being as 2:1. (Hendy.)

Fall per Mile.	Fall per Rod.	T 6 ft. B 2 ft. D 1 ft. Section 4 sq. ft.	T 9 ft. B 3 ft. D 1.5 ft. Section 9 sq. ft.	T 12 ft. B 4 ft. D 2.5 ft. Section 16 sq. ft.	T 16 ft. B 6 ft. D 2.5 ft. Section 27.5 sq. ft.	T 22 ft. B 10 ft. D 3 ft. Section 48 sq. ft.	T 28 ft. B 12 ft. D 4 ft. Section 30 sq. ft.	T 40 ft. B 20 ft. D 5 ft. Section 150 sq. ft.
ft.	in.	cu. ft.	cu. ft.	cu. ft.	cu. ft.	cu. ft.	cu. ft.	cu. ft.
.5	.01875	1.27	3.55	8.63	18.11	38.79	78.2	138.1
.6667	.0250	1.46	4.44	9.96	20.91	44.79	90.3	217.2
.8333	.03125	1.63	4.96	11.14	23.38	50.08	101.0	242.8
1.	.0375	1.79	5.44	12.20	25.61	54.86	110.6	266.0
1.25	.046875	2.00	6.09	13.64	28.68	61.32	123.7	297.4
1.5	.05625	2.19	6.67	14.96	31.34	67.26	135.7	326.1
1.75	.065625	2.37	7.19	16.14	33.88	72.57	146.4	351.8
2.	.0750	2.53	7.69	17.26	36.23	77.58	156.5	376.1
2.25	.084375	2.68	8.16	18.30	38.42	82.29	165.9	399.0
2.5	.09375	2.83	8.60	19.29	40.50	86.72	174.9	420.6
3.	.1125	3.10	9.42	21.14	44.36	93.00	191.6	460.7
3.5	.13125	3.35	10.17	22.83	47.91	103.60	207.0	497.6
4.	.1500	3.58	10.87	24.41	51.22	109.70	221.3	531.9
4.5	.16875	3.79	11.54	25.88	54.33	116.30	234.7	564.2
5.	.1875	4.00	12.16	27.29	57.27	122.70	247.4	594.8
6.	.2250	4.38	13.31	29.89	62.74	134.40	271.0	651.5
7.	.2625	4.73	14.39	32.29	67.78	145.10	292.7	703.6
8.	.3000	5.06	15.38	34.52	72.43	155.20	312.9	752.2
9.	.3375	5.37	16.31	36.61	76.83	164.60	331.9	797.9
10.	.3750	5.66	17.19	38.59	80.89	173.50	349.9	841.1
11.	.4125	5.93	18.03	40.47	84.94	181.90	366.9	882.1
12.	.4500	6.20	18.74	42.27	88.72	190.10	383.2	921.3

T signifies top width; B, bottom width; D, depth.

*Water*—continued.

Let  $H$  = total height from source of supply to tail-race;

$h$  = effective height of fall at end of channel;

$l$  = length of the channel;

$S$  = cross-section „

$i$  = inclination „

$Q$  = discharge „

$v$  = mean velocity of the current.

$$\text{Then} \quad H = h + li \quad \dots \dots \dots (1)$$

and  $Qh = Q(H - li)$  = effective motive force at disposal.

$$\text{Also} \quad Q = Sv \quad \dots \dots \dots (2)$$

$$\text{and} \quad i = m v^2 \quad \dots \dots \dots (3)$$

where  $m$  is a coefficient depending on the section of the channel and the nature of its walls or banks.

From (2) and (3) the available work will be found to be:—

$$Sv(H - lmv^2).$$

Then,  $v$  being the variable, the maximum:—

$$H = 3lmv^2;$$

or, from (3),

$$li = \frac{1}{3}H.$$

Now  $li$  is the height lost by the gradient or inclination of the channel. Consequently: of all channels of a given length and section, that which supplies the greatest motive-power at its extremity is the one whose inclination is equal to one-third of the total fall, leaving two-thirds of the height available for motive purposes.

*Remarks.* (1) The above applies to cases where part only of the water is taken off by the canal. If the whole stream is diverted, the gradient should be limited to that strictly necessary, so as to utilise the greatest possible height of fall.

(2) The gradient must of course be limited by the velocity which the banks of the canal can stand without damage.

(3) In practice, the gradient would not be constant throughout. In parts where the construction is difficult and expensive, a greater fall and smaller cross-section would be adopted, and *vice versa*; but the above rule, without being mathematically correct, will furnish a useful guide for the mean average gradient.



Water—continued.

Area of discharge .. .. .	0.147 sq. ft.
Velocity .. .. .	2.00 ft.
Perimeter .. .. .	1.18 "
Grade .. .. .	0.0035 ft.
Actual discharge .. .. .	0.287 cub. ft.
Theoretical grade .. .. .	0.0032 "

Discharge of double flume is 0.168 more than two singles  
on this grade.

Third Experiment on Grade ; grade  $\frac{3}{4}$  in. to 12 ft. = 0.0052.

Area of discharge .. .. .	0.295 sq. ft.
Velocity .. .. .	2.8 ft.
Perimeter .. .. .	2.02 "
Grade .. .. .	0.0052 ft.
Actual discharge .. .. .	0.827 cub. ft.
Theoretical grade .. .. .	0.0053 "

Area of discharge .. .. .	0.147 sq. ft.
Velocity .. .. .	2.21 ft.
Perimeter .. .. .	1.18 "
Grade .. .. .	0.0052 "
Actual discharge .. .. .	0.325 cub. ft.
Theoretical grade .. .. .	0.0035 "

Discharge of double flume is 0.272 more than two singles  
on this grade.

*The least wet perimeter that will hold or carry a given volume is attained when the width of bottom is  $1\frac{3}{4}$  to  $2\frac{1}{4}$  times the depth of the sides.*—For example, a channel having a cross-section of 510 sq. in. will develop the least amount of friction when its dimensions are 15 by 34, or 17 by 30, or somewhere between these measurements. A knowledge of this fact will be found serviceable in constructing flumes. The least perimeter, of course, requires the least lumber, and many thousand or million feet may be saved in a long flume by building in the correct proportion.

When the head of the flume is above timber line, or in high altitudes where ice forms early in the fall, it is an advantage in many respects to have it so narrow in width that an ice-crust can easily form itself from bank to bank. If this is secured, water will often flow 4-6 weeks longer than otherwise. The reasons are obvious.

The ordinary figures representing loss through evaporation ( $\frac{1}{10}$  to  $\frac{3}{10}$  in. of surface per day) are much too small for ditches above an altitude of 6000 ft. Evaporation also proceeds much more rapidly

*Water—continued.*

in shallow water than in deep, and when the velocity is high. Experiments made on a 12-mile wooden flume on the Swan River, Colorado, indicated a loss of 10–18 per cent. daily. This flume is, however, an extreme case, being about 10,000 ft. above sea-level. Probably 1 in. of surface would be an average loss.

Leakage occurs most extensively in gravelly soils; 1–5 in. of surface per day are extreme losses, with an average, perhaps, of about 2 in., which it will be always safe to count on, except in old ditches. A high velocity decreases loss through the soil.

Water channels of uniform section should always have a uniform grade, otherwise there will be an accumulation at some points and a thinning-out at others, with deposits of sand and silt, and increased danger of breakage. It is also highly advantageous in earth ditches to have a complete system of waste-weirs to carry off surplus waters occasioned by floods, and to lessen the damage of breaks. These should be put in just below wherever a new stream falls into the ditch, and just above those places where, by reason of a shelly or crumbly soil, the ditch is weak.

At high altitudes in the spring, difficulty is often encountered in starting the water through heavy accumulations of snow in the ditch, which if long, can be flushed out only with great trouble. This operation will be materially hastened if the ditch is cleaned out in sections of a mile or two each. Cut a hole in the bank a mile from the head, and when the water has soaked that far it will carry off the unmelted snow through this break with great rapidity. As soon as clear, that hole is mended and another is made a mile farther on. (Von Wagenen.)

*Cost of Ditching.*—When the plough and scraper can be used, ditching can be done at 20 c. (10*d.*) per cub. yd. If the soil is so rocky as to call for the pick and shovel, it will cost 30–40 c. (15–20*d.*) A safe figure to be taken for the construction of a ditch 3 ft. wide at bottom, 4½ ft. wide at top, and 18 in. deep is 15*s.* 3*d.* per rod. It can be done for less. The larger the ditch the less costly it will be in proportion. These figures are based on Californian rates of wages. (Von Wagenen.)

*Cost of Ditching.* (Kirkpatrick.)

Labour calculated at 6*d.* per hour.

Rock:—

	s.	d.
Excavating .. .. .	2	0
Wheeling .. .. .	0	9
Dressing .. .. .	0	9
Superintendence .. .. .	0	6

4 0 per cub. yd.

Water—continued.

Gravel and Clay:—

	s.	d.
Excavating and wheeling .. .. .	1	0
Levelling ditch .. .. .	0	6
Making up removed material .. .. .	0	6
Superintendence .. .. .	0	6
	<hr/>	
	2	6 per cub. yd.

Total cost, at 4 cub. yd. excavation, per yd. run:—

	s.	d.
Rock, $1\frac{1}{2}$ cub. yd., @ 4s. .. .. .	6	0
Gravel, $2\frac{1}{2}$ cub. yd. @ 2s. 6d. .. .. .	6	3
	<hr/>	
	12	3 per yd. run,

or 1078*l.* per mile.

To find what grade per foot must be given to a flume or ditch of uniform section to enable it to discharge a given quantity of water in a given time. Divide the number of cub. ft. of discharge required by the area in sq. ft. of the section of the flume. This result is the necessary velocity in ft. per second. Multiply this result by itself. Multiply this product by the wet perimeter in ft., and multiply this product by .0001114. Divide this product by the area of the section of flume in sq. ft. Call the result A. Multiply the velocity in ft. per second by the wet perimeter in ft., and multiply this product by .00002426. Divide this product by the area of the section of the flume in sq. ft. Call the quotient B. Add together A and B. The result is the grade per ft. in decimals of a ft. which must be given to the flume to make it carry the required water. *Ex.*—What grade per ft. of length must be given to a 20-in. flume whose sides are 11 in. high, in order that it may deliver 28 cub. ft. of water per second steadily? *Ans.*—Wet perimeter, 42 in. = 3.5 ft. Area of section, 240 sq. in. = 1.66 sq. ft. Discharge = 28 cub. ft. Then, dividing the discharge (28) by the area of section (1.66), we have 16.86 as the velocity in ft. per second. The velocity (16.86) multiplied by itself equals 284.25; multiplying this by wet perimeter (3.5) produces 994.87; multiplying again by .0001114 produces .1108; dividing this by area of section (1.66) gives .0667. Call this A. Multiplying the velocity (16.86) by wet perimeter (3.5), and the product by .00002426, produces .0014315, which divided by the area of the section of the flume (1.66) = .00086. Call this B. Adding A (.0667) to B (.00086), we have as a final result .06756, which is the grade per ft. in decimals of a ft. If we multiply this result (.06756) by 1000, we have the grade per 1000 ft., which will be 67.5 ft. To reduce this result to the ordinary terms—viz. in. per box of 12 ft.—divide first 1000 by 12, which produces 83.33 (which of course

*Water—continued.*

represents the number of 12-ft. boxes in a 1000-ft. flume). Then, the grade being 67·5 ft. in 83·33 boxes, for each box, it would be the result of dividing 67·5 by 83·33, which is ·79, or the grade would be ·79 ft. per box of 12 ft. Finally, there being 12 in. in a ft., we multiply ·79 by 12 and obtain 9·48 in. per box, or nearly 9½ in. (Von Wagenen.)

To find the average velocity and discharge secured in a flume or ditch of uniform cross-section and grade. Multiply area of cross-section in sq. ft. by the grade in ft. per ft., and the product by 9000. Divide this result by the wet perimeter in ft. Extract the square root of the quotient. From the result subtract ·1089. The result equals the mean velocity of the water in ft. per second. Multiply the area of cross-section by the mean velocity. The result equals the discharge in cub. ft. per second. *Ex.*—What is the discharge attained in a 30-in. flume with 12-in. sides, having a uniform grade of  $\frac{1}{100}$  (·01 ft. for every ft. of length)? *Ans.*—Multiplying the area of cross-section (2·5 sq. ft.) by the grade (·01) produces ·025; multiplying this by 9000 yields 225; dividing this by the wet perimeter (4·5) gives 50, whose square root is 7·0711; subtracting from this the decimal ·1089, we have 6·9622, which is the mean velocity in ft. per second. This is accurate only for a flume. In a ditch, where friction is greater, it will be necessary to subtract about 10 per cent. (or ·6962) from the result found, leaving 6·266 as the correct figure. Then multiply the mean velocity (6·9622) by the area of cross-section (2·5); we have 17·40, which is the discharge in cub. ft. per second. (Von Wagenen.)

To find the section of a ditch or flume of uniform grade which will discharge a given quantity of water in a given time. There is no simple rule that will solve this problem, and an answer must be sought experimentally upon the following plan:—Assume a convenient section, and, the grade being known, calculate its discharge. If this discharge is greater or less than the required one, try again with a smaller or larger section until the correct one is found. (Von Wagenen.)

*Cost.*—With lumber at 12 to 15 dols. per 1000, delivered at the head of the flume, so that it can be floated down, a flume 2½ ft. wide and 2½ ft. high can be finished at a cost of 3·85 dols. (16s.) per box (of 12 ft. in length); and one 6 ft. wide and 3½ ft. high at 8½ dols. (35s. 6d.) per box, at Californian rates. (Von Wagenen.)

#### WATER: *Piping.*

To find the velocity attained in a cylindrical iron pipe, laid straight or with easy curves, its head, length, and diameter being known. Multiply the diameter in ft. by the head in ft. Call this product A. Add together the total length of pipe in ft., and 54 times its diameter in ft. Call this sum B. Divide A by B. Extract the square root of the quotient; multiply this root by 48. The product will be the velocity in ft. per second. *Ex.*—What velocity



*Water—continued.*

will be attained in a pipe 12,600 ft. long, 6 in. (.5 ft.) in diameter, and having a head of 200 ft.? *Ans.*—Multiply diameter (.5) by head (200) = 100. Call this product A. Add to the total length (12,600 ft.) 54 times its diameter: .5 multiplied by 54 equals 27 = 12,627. Call this sum B. Divide A (100) by B (12,627) = .0079. Extract the square root of this result, which = .0889. Multiply this root by 48 = 4.26, which is the velocity per second in ft. (Von Wagenen.)

*To find how many cub. ft. of water per second will be discharged from a cylindrical iron pipe, straight or with easy curves, its head, length, and diameter being known.* Ascertain the velocity by preceding rule. Then multiply the velocity thus attained by the area in sq. ft. of a section of the pipe. The result will be the discharge per second in cub. ft. (Von Wagenen.)

*To find what head of water is necessary for a cylindrical iron pipe, straight or with easy curves, its diameter and length being known, to produce a given discharge per second.* Multiply the required discharge in cub. ft. by itself. Call this A. To the total length of pipe add 54 times its diameter. Call this B. Multiply A by B. Call the product C. Divide the diameter in ft. by .235. Multiply this product by itself continuously four times. Divide C by this product. The quotient will be the head in ft. *Ex.*—What head is necessary to produce a discharge of 12 cub. ft. per second at the end of a pipe 8 in. (.666 ft.) diameter and 350 ft. long, the pipe being straight or with easy curves? *Ans.*—Multiply the discharge (12) by itself = 144; call this A. To the total length (350) add 54 times its diameter (36) = 386; call this B. Multiply A (144) by B (386) = 55,584 (C). Divide the diameter (.666) by .235 = 2.834. Multiply this product (2.834) by itself continuously four times = 182.801. Divide C (55,584) by this product (182.801) = 304 ft. nearly, which is the required head. (Von Wagenen.)

*To find diameter of pipe necessary to carry a given quantity of water per second, its length and total head being known.* Multiply the head in ft. by 5280, and divide the product by the length in ft. Call this A. Multiply the discharge in cub. ft. per second by itself, and multiply this product by 5280. Call this B. Divide B by A. Extract the fifth root of the result. Multiply this by .235. The product is the diameter in ft. *Ex.*—What must be the diameter of a pipe 6000 ft. long, with a head of 400 ft., which will discharge 6 cub. ft. of water per second? *Ans.*—Multiply the head (400) by 5280 = 2,112,000, and divide this product by the length (6000) = 352 (A). Multiply the discharge (6) by itself = 36, and multiply this product by 5280 = 190,080 (B). Divide B (190,080) by A (352) = 540. Extract fifth root of this quotient (540) = 3.52. Multiply this root (3.52) by .235 = .8272, which is the required diameter in decimals of a ft. (Von Wagenen.)

*To find loss of head by friction in pipes,* refer to Table 18, which is calculated for pipes 100 ft. long. Column *a* shows velocity of flow

Water—continued.

in ft. per second; *b*, discharge in cub. ft. per minute; *c*, cub. ft. loss by friction. The bold figures at top of column indicate inside diameter of pipes in inches.

Table 18.—Loss of Head by Friction.

<i>a</i>	3		4		5		6		7		8	
	<i>b</i>	<i>c</i>	<i>b</i>	<i>c</i>	<i>b</i>	<i>c</i>	<i>b</i>	<i>c</i>	<i>b</i>	<i>c</i>	<i>b</i>	<i>c</i>
1	2'95	1'96	5'22	1'47	8'17	1'18	11'77	0'98	16'03	0'84	20'88	0'74
2	5'89	6'59	10'44	4'94	16'34	3'95	23'54	3'29	32'05	2'82	41'76	2'47
3	8'83	1'35	15'67	1'02	24'51	8'15	35'32	6'79	48'08	5'81	62'64	5'09
4	11'80	2'28	20'89	1'71	32'69	1'37	47'09	1'14	64'11	9'77	83'52	8'56
5	14'70	3'43	26'12	2'57	40'87	2'05	58'87	1'71	80'15	1'47	104'40	1'28
6	17'70	4'78	31'34	3'59	49'05	2'87	70'64	2'39	96'18	2'05	125'28	1'79
7	20'60	6'35	36'57	4'77	57'22	3'81	82'41	3'18	112'21	2'73	146'16	2'39
8	23'56	8'14	41'79	6'11	65'40	4'89	94'19	4'07	128'24	3'49	167'04	3'06
9	26'51	10'12	47'02	7'59	73'57	6'07	105'97	5'06	144'27	4'34	187'92	3'79
10	29'45	12'32	52'24	9'24	81'75	7'39	117'74	6'16	160'30	5'28	208'80	4'62
11	32'40	14'71	57'47	11'03	89'92	8'82	129'52	7'36	176'34	6'31	229'68	5'52
12	35'34	17'31	62'70	12'98	98'10	10'38	141'30	8'65	192'37	7'41	250'56	6'49
13	38'33	20'10	67'92	15'08	106'27	12'06	153'07	10'05	208'40	8'61	271'44	7'54
14	41'23	23'12	73'15	17'34	114'45	13'87	164'85	11'56	224'43	9'91	292'32	8'67
15	44'20	26'32	78'38	19'74	122'62	15'79	176'63	13'16	240'46	11'28	313'20	9'87
16	47'12	29'72	83'60	22'29	130'80	17'83	188'40	14'86	256'48	12'74	334'08	11'15
17	50'05	33'33	88'83	25'00	138'97	20'60	200'18	16'67	272'51	14'29	354'96	12'50
18	53'00	37'14	94'05	27'86	147'15	22'29	211'86	18'57	288'54	15'92	375'84	13'93
19	55'95	41'12	99'28	30'84	155'32	24'67	223'73	20'56	304'57	17'62	396'72	15'42
20	58'89	45'32	104'50	33'99	163'50	27'19	235'51	22'66	320'60	19'42	417'60	17'00

<i>a</i>	9		10		11		12		13		14	
	<i>b</i>	<i>c</i>	<i>b</i>	<i>c</i>	<i>b</i>	<i>c</i>	<i>b</i>	<i>c</i>	<i>b</i>	<i>c</i>	<i>b</i>	<i>c</i>
1	26'47	0'65	32'70	0'69	39'55	0'54	47'10	0'49	55'30	0'45	64'08	0'42
2	52'94	2'20	65'40	1'98	79'10	1'80	94'20	1'64	110'60	1'52	128'16	1'41
3	79'41	4'50	98'15	4'07	118'65	3'70	141'30	3'39	165'90	3'13	192'24	2'91
4	105'90	7'60	130'85	6'85	158'20	6'23	188'40	5'70	221'20	5'27	256'32	4'89
5	132'37	1'14	163'50	1'03	197'76	9'32	235'40	8'55	276'50	7'89	320'40	7'35
6	158'84	1'59	196'20	1'43	237'30	1'30	282'50	1'20	331'80	1'10	384'48	1'03
7	185'31	2'12	228'90	1'90	276'85	1'73	329'60	1'59	387'10	1'46	448'57	1'36
8	211'80	2'71	261'60	2'45	316'40	2'23	376'70	2'04	442'40	1'88	512'66	1'75
9	238'29	3'37	294'29	3'03	355'95	2'76	423'80	2'53	497'70	2'33	576'75	2'17
10	264'77	4'11	327'00	3'70	395'50	3'36	470'90	3'08	553'00	2'85	640'84	2'64
11	291'26	4'90	359'70	4'41	435'05	4'01	518'00	3'68	608'30	3'39	704'93	3'15
12	317'74	5'77	392'39	5'19	474'62	4'72	565'10	4'32	663'60	3'99	769'02	3'71
13	344'22	6'70	425'09	6'03	514'17	5'48	612'20	5'03	718'90	4'64	833'10	4'30
14	370'70	7'71	457'79	6'93	553'72	6'30	659'30	5'78	774'20	5'33	897'18	4'95
15	397'18	8'77	490'49	7'90	593'27	7'18	706'35	6'58	829'50	6'08	961'27	5'64
16	423'65	9'91	523'18	8'92	632'82	8'11	753'45	7'43	884'75	6'86	1025'36	6'37
17	450'13	11'11	555'88	10'00	672'37	9'09	800'50	8'33	900'00	7'69	1089'45	7'15
18	476'61	12'38	588'58	11'14	711'92	10'13	847'60	9'29	995'30	8'57	1153'59	7'96
19	503'08	13'71	621'28	12'34	751'52	11'22	894'70	10'28	1050'60	9'49	1217'63	8'81
20	529'56	15'11	653'98	13'60	791'07	12'36	941'75	11'33	1105'90	10'46	1281'72	9'71

Table 18.—*continued.*

a	15		16		17		18		19		20	
	b	c	b	c	b	c	b	c	b	c	b	c
1	73.58	.039	83.68	.037	94.56	.035	106.00	.033	118.09	.031	130.87	.029
2	147.16	.132	167.36	.123	189.12	.116	212.00	.110	236.18	.104	261.74	.099
3	220.74	.272	251.04	.255	283.68	.239	318.00	.225	354.27	.214	392.61	.204
4	294.32	.457	334.72	.428	378.24	.403	424.00	.380	472.36	.361	523.48	.343
5	367.90	.683	418.40	.640	472.80	.601	530.00	.570	590.45	.537	654.35	.515
6	441.48	.957	502.08	.895	567.36	.841	636.00	.795	708.54	.753	785.22	.715
7	515.07	1.27	585.76	1.19	661.92	1.12	742.00	1.06	826.63	1.00	916.09	.950
8	588.66	1.63	669.45	1.53	756.48	1.44	848.00	1.36	944.72	1.29	1046.96	1.23
9	662.25	2.02	753.14	1.89	851.04	1.78	954.00	1.68	1062.81	1.59	1177.83	1.51
10	735.84	2.46	836.83	2.31	945.60	2.18	1060.00	2.06	1180.90	1.95	1308.70	1.85
11	809.43	2.94	920.52	2.76	1040.16	2.59	1166.00	2.45	1298.99	2.32	1439.57	2.21
12	883.02	3.46	1004.21	3.24	1134.72	3.05	1272.00	2.89	1417.08	2.73	1570.44	2.59
13	966.60	4.02	1087.90	3.77	1229.28	3.55	1378.00	3.35	1535.17	3.17	1701.31	3.02
14	1030.18	4.62	1171.59	4.33	1323.84	4.08	1484.00	3.86	1653.26	3.65	1832.18	3.47
15	1103.77	5.26	1255.28	4.93	1480.40	4.65	1590.00	4.38	1771.35	4.16	1963.05	3.95
16	1177.36	5.94	1338.96	5.58	1512.96	5.25	1696.00	4.96	1889.44	4.69	2093.92	4.46
17	1250.95	6.67	1422.64	6.25	1607.52	5.88	1802.00	5.55	2007.53	5.26	2224.79	5.00
18	1324.54	7.43	1506.32	6.97	1702.08	6.55	1908.00	6.19	2125.62	5.86	2355.66	5.57
19	1398.13	8.22	1590.00	7.71	1796.64	7.26	2014.00	6.86	2243.71	6.49	2486.53	6.17
20	1471.72	9.06	1673.68	8.50	1891.20	8.00	2120.00	7.56	2361.80	7.16	2617.40	6.80

a	22		24		26		28		30	
	b	c	b	c	b	c	b	c	b	c
1	158.36	.027	188.44	.025	221.13	.023	256.56	.021	294.44	.019
2	316.72	.090	376.88	.082	442.26	.076	513.12	.071	588.88	.066
3	475.03	.185	565.32	.169	663.39	.157	769.68	.145	883.32	.136
4	633.44	.312	753.76	.285	884.52	.263	1026.24	.245	1177.76	.228
5	791.80	.466	942.20	.428	1105.65	.394	1282.80	.368	1472.20	.342
6	950.16	.650	1130.64	.600	1326.78	.550	1539.36	.515	1766.64	.478
7	1108.52	.865	1319.08	.795	1547.91	.730	1795.92	.680	2061.08	.635
8	1266.88	1.12	1507.52	1.02	1769.04	.940	2052.48	.875	2355.52	.815
9	1425.24	1.38	1695.96	1.27	1990.17	1.17	2309.04	1.08	2649.96	1.01
10	1583.60	1.68	1884.40	1.54	2211.30	1.42	2565.60	1.32	2941.40	1.23
11	1741.96	2.01	2072.84	1.84	2432.43	1.69	2822.16	1.57	3238.84	1.47
12	1900.32	2.36	2261.28	2.16	2653.56	2.00	3078.72	1.86	3533.28	1.73
13	2058.68	2.74	2449.72	2.52	2874.69	2.32	3335.28	2.15	3827.72	2.01
14	2217.04	3.15	2638.16	2.89	3095.82	2.67	3591.84	2.48	4122.16	2.31
15	2375.40	3.59	2826.60	3.29	3316.95	3.04	3848.40	2.82	4416.60	2.63
16	2533.76	4.06	3015.04	3.72	3538.08	3.43	4104.96	3.19	4711.04	2.97
17	2692.12	4.55	3203.48	4.17	3759.21	3.85	4361.52	3.68	5005.48	3.33
18	2850.48	5.07	3391.92	4.65	3980.34	4.29	4618.08	3.98	5299.92	3.72
19	3008.84	5.61	3580.36	5.14	4201.47	4.75	4874.64	4.41	5594.36	4.11
20	3167.20	6.18	3768.80	5.67	4422.60	5.23	5131.20	4.86	5888.80	4.53

WATER: *Flow in Siphons.* (Vodicka.)

In spite of many observations, the nature of the resistance attending the motion of water in pipes is still far from clear. It is

*Water*—continued.

known that the resistance increases with the length of the pipe and with the diminution of the diameter, and the formula of Weisbach (1) is generally used for determining the velocity of outflow.

$$v = \sqrt{\frac{2gh}{1 + \eta_0 + \eta \frac{l}{d}}} \quad . . . . . (1)$$

and

$$h_2 = \eta \frac{v^2}{2g} \cdot \frac{l}{d} \quad . . . . . (2)$$

represents the loss of head due to the frictional resistance. A series of experiments upon a large siphon belonging to the waterworks of Romeno, in Nonsthal, show that the resistance is influenced not only by the velocity of flow, the diameter and length of the pipe, but also to a great extent by the hydraulic pressure on the sides of the pipe. It is a physical fact that the resistance in a pipe full of flowing water does not arise from friction against the pipe itself, but against a thin layer of water which adheres to it. The thickness of these layers, which are quite still or move very slowly, depends on the pressure upon the sides of the pipe. The greater this is, the thicker will be the layer, and therefore the smaller will be the diameter of the free area for flowing. In pipes with a constant or slightly varying fall, the line of hydraulic pressure is about parallel with the pipe. In such a case the pressure is almost the same in every part, and the resistance may be taken as proportional to the length. It is different in the case of a siphon, when the hydraulic pressure varies very much.

At the Romeno waterworks the supply is collected from some springs and from the Ruffré stream into a tank, whence it goes into a masonry and concrete conduit by many curves along the faces of the hills and cliffs, for a distance of about 15 furlongs, to Cavareno, where is a second tank. From this it passes by means of a siphon 938·8 yd. long across the Moscabia valley into a third tank, whence it flows on to Romeno along a second conduit about 15 furlongs in length.

The siphon consists of cast-iron socket pipes, 5 in. internal diam., and has an outlet at the lowest point. In the experiments the water was collected at its outflow in gauged reservoirs, and more water was always brought to the upper end of the siphon than it could take. Three sets of experiments were made, I., II., III., by admitting the water at three points in the siphon on one side of the valley, and letting it off at three points on the other side. In I., where the head was 4·233 m. (13·89 ft.), and the length 553 m. (1814 ft.), the mean of three experiments gave a flow of 8·867 litres

*Water—continued.*

per second (117.2 gal. per minute), equivalent to a velocity of 0.651 m. (2.136 ft.) per second, whereas the Weisbach formula gives a velocity of 0.895 m. per second.

In II. the head was 7.1 m. (23.29 ft.), and the length 517.2 m. (1697 ft.). The mean of five experiments (varying from 8.526 to 8.645) was 8.567 litres per second, equivalent to a velocity of 0.63 m. per second, whereas the formula gives a velocity of 1.227 m. per second.

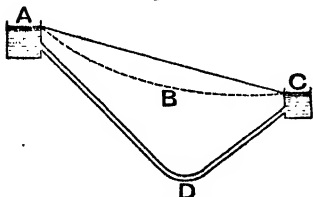
In III. the head was 19.935 m. (65.405 ft.), and the length 858.4 m. (2816 ft.). The experiments each gave a flow of 20.25 litres per second, equivalent to a velocity of 1.487 m. per second, whereas the formula gives 1.645.

In such experiments it is important that the gauging should not be commenced until the water has been flowing for some time, or until the bubbles caused by the compression of the air, when the water first flows into the bottom of the bend of the siphon, have ceased to rise. For instance, in the third experiment it was almost  $\frac{1}{2}$  hour before the bubbles ceased, and a measurement made at first gave only 13.5 litres per second, as compared with the later flow of 18.55 litres.

In every case the outflow of water varies considerably from the amount given by the formula, especially in II., where the head is greater and the sum of the hydraulic side-pressures smaller than in I., and yet the outflow is less. This may be explained as follows:—By the increased head in II. (in comparison with I.) the velocity would be increased, thus the hydraulic pressure would be somewhat lessened, as also would the thickness of the layers of water adhering to the wall of the pipe. The loss of head from friction would, however, be greater, being proportional of the square of this increased velocity. In this way almost the whole of the excess of head in II. over I. is used up. It is clear that the

water cannot flow out with less velocity in II. than in I.; therefore, since less water has flowed out, the area of the outflow must have been less, which agrees with the fact that the outflow lies lower than in I., and there is therefore a greater wall-pressure. This indicates that the diminution of the cross-section occurs through increased wall-pressure by the

Fig. 6.



Loss of Head in Pipes.

formation of layers of still or almost still water on the wall of the pipe.

In III., with a head of 21 m., the flow of water is greatly increased, and agrees fairly with that arrived at by using the formula, the increased head having overcome the resistance met with.

*Water*—continued.

From what goes before it follows that the loss of head in pipes is some function of the sum of all the hydraulic side pressures, that is a function of the area *A B C D* (Fig. 6) or approximately of the area *A C D*, included between the pipe and the straight line joining its ends.

Substituting in formula (2) *F* for *l*,

$$h_2 = \eta \cdot \frac{F}{d} \cdot \frac{v^2}{2g} \quad \dots \quad (3)$$

Where *d* is the diameter of pipe, *v* is the velocity of outflow, and *F* the area *A C D* in sq. m.; and from (1) substituting *F* for *l*,

$$h = (1 + \eta) \frac{v^2}{2g} + \eta \frac{F}{d} \cdot \frac{v^2}{2g} \quad \dots \quad (4)$$

The influence of bends is left out of consideration. Applying this formula to the data obtained from experiments I., II., III., and a fourth made subsequently with a head of 16 m., the value of the coefficient  $\eta$  is determined in each case, and a curve constructed showing the varying values of  $\eta$  as *h* increases, which gives the following results:—

<i>h</i> =	1	2	3	4	5	6	7	8	9	10
$\eta = 0.00$	05	11	20	34	58	74	79	80	77	70
<i>h</i> =	11	12	13	14	15	16	17	18	19	20
$\eta = 0.00$	61	51	41	33	26	20	16	135	12	115

*Hydraulic Grade-line.*—This is an imaginary straight line, extending from a point on the side of the reservoir denominated the velocity-head, to the outlet of the pipe. If the pipe be constructed exactly on this line, the water flowing through it, no matter what its velocity or volume, will exert no bursting pressure. In other words, the grade of the hydraulic grade-line is such that the velocity caused by the grade is exactly sufficient to carry down all that the pipe will hold, and there is no outward pressure exerted except that on the bottom of the pipe due to the water's weight. If, however, there be a change in the diameter of the pipe at any point, this equilibrium ceases to exist. It is never possible in practice to adopt this line as a course, but generally close approximations can be made to it, and it is highly advantageous to do this wherever possible.

*Water—continued.*

*To find the Hydraulic Grade-line.*—Calculate the velocity in pipe due to the total head. Find the head corresponding to this velocity. Lay off this head on the side of the reservoir from the top of the pipe-opening. Its termination will mark the line of the velocity-head. From this point sight to the outlet of the pipe; the line of sight is the hydraulic grade-line.

In constructing a line of piping three cases may arise by reason of the inequalities of the ground to be passed over: (a) The pipe may lie below the hydraulic grade-line; (b) above it; (c) both above and below.

*Pipe below Hydraulic Grade-line.*—Here is a bursting pressure, varying in power according to its distance below the line. To find this pressure at any point, ascertain the distance of that point vertically below the hydraulic grade-line. Call this measurement the bursting-head—say 6 ft. The pressure, then, on each sq. in. of pipe at that point is equal to the weight of a column of water whose base measures 1 sq. in. and whose height is 6 ft. Thus, 1 sq. in. multiplied by 6 ft. (72 in.) = 72 cub. in. = .04166 cub. ft. multiplied by 62.5 (wt. of cub. ft. of water) = 2.6 lb., which is the pressure per sq. in. Consequently, if the pipe lies considerably below the hydraulic grade-line, it will need to be of thicker iron than the rest. This law applies in crossing deep hollows.

*Pipe above the Hydraulic Line.*—Here is a decided loss of head, and consequently of power, in portions of the pipe, if it be the same diameter throughout. Find now that point in the pipe which is highest above the hydraulic grade-line, and from that point draw two new grade-lines, one to the pressure-box and one to the outlet. Along the former calculate the bursting pressure as above, measuring the different heads from the new line. Along the latter there will be no bursting pressure, for the grade of the outlet end of the pipe will be so much greater than that of the reservoir end that it will carry off the water very much faster, and will, in fact, act like a gutter, and be partially empty. The remedy for this is to put in pipes having a decreased diameter. To calculate the requisite diameter, assume that the pipe ended at that point where it is highest above the hydraulic grade-line. Calculate the discharge in cub. ft. at that point. This will give the amount of water in cub. ft. per second which the outlet section must carry. The head will be the vertical distance from the highest to the lowest point.

*Pipe both above and below the Hydraulic Grade-line.*—The problem now becomes more complicated. Divide the pipe into sections for every passage it makes above the hydraulic grade-line, and make the divisions at the several points where the pipe attains its highest position. Calculate the discharge at the end of each section. The first section will have a head equal to the vertical distance between its discharge and the water-level in the pressure-box. All succeed-

Water—continued.

ing heads will be measured from the level of the discharge just below them to their own discharge. These measurements will furnish a series of heads and grades from which the diameters of pipe necessary may be calculated.

Table 19.—WATER: *Strength of Sheet-iron Piping.* (Von Wagenen.)

This table gives the thickness, in inches and decimals of an inch, which iron piping must have to stand a given pressure.

Diameter of Pipe, in inches.	Head of Water, in ft.									
	100	150	200	250	300	400	500	600	800	1000
	Resulting Pressure against Sides of Pipe, in lb. per sq. in.									
	43·4	65·1	87	109	130	174	217	260	347	434
Required Thickness of Pipe, in inches or decimals of an inch.										
2	·009	·013	·018	·022	·027	·036	·045	·055	·075	·095
3	·013	·020	·026	·033	·040	·054	·068	·082	·112	·143
4	·017	·026	·035	·045	·053	·072	·090	·110	·149	·191
5	·022	·033	·044	·056	·067	·090	·113	·137	·186	·237
6	·026	·040	·053	·067	·080	·108	·136	·165	·224	·287
7	·030	·046	·062	·078	·093	·126	·159	·193	·261	·333
8	·034	·053	·071	·089	·107	·144	·181	·220	·298	·382
9	·039	·059	·079	·101	·120	·163	·205	·247	·335	·427
10	·044	·066	·089	·112	·134	·181	·227	·275	·373	·475
12	·053	·080	·106	·134	·161	·217	·273	·330	·448	·575
14	·061	·093	·124	·156	·187	·253	·318	·387	·523	·666
16	·069	·106	·142	·178	·214	·288	·363	·440	·596	·763
18	·078	·120	·159	·201	·242	·326	·409	·495	·670	·850
20	·088	·132	·177	·223	·267	·361	·454	·549	·746	·950
24	·105	·159	·213	·268	·321	·433	·545	·660	·895	1·150
30	·132	·198	·267	·336	·402	·543	·681	·825	1·120	1·420
36	·156	·238	·318	·402	·483	·651	·819	·990	1·340	1·710
42	·184	·279	·372	·469	·562	·759	·955	1·160	1·570	2·000
48	·210	·317	·425	·535	·641	·866	1·090	1·320	1·790	2·290

To find what thickness of iron should be used to make a 20-in. pipe which must bear 200 ft. head of water.—The figure given in the table is ·177 in., which, by the following table, corresponds to between No. 5 and No. 6 iron. Or, the head being 100 ft. and the pipe 10 in. diameter, the thickness will be ·044 in., which corresponds nearly to No. 22. In selecting the iron it will always be safer to take the size one larger than that called for by the figures,



TABLE 20.—WATER: *Thickness of the different sizes of sheet-iron from No. 4 up to No. 30.*

No. 4 has a thickness of .250 in.			No. 18 has a thickness of .055 in.		
" 5	"	.200 "	" 19	"	.052 "
" 6	"	.166 "	" 20	"	.050 "
" 7	"	.142 "	" 21	"	.047 "
" 8	"	.133 "	" 22	"	.046 "
" 9	"	.111 "	" 23	"	.044 "
" 10	"	.100 "	" 24	"	.041 "
" 11	"	.090 "	" 25	"	.040 "
" 12	"	.083 "	" 26	"	.038 "
" 13	"	.076 "	" 27	"	.037 "
" 14	"	.071 "	" 28	"	.035 "
" 15	"	.066 "	" 29	"	.034 "
" 16	"	.062 "	" 30	"	.033 "
" 17	"	.058 "			

In practice the depression of the pipe leading from the water-box to the pit is rarely more than 5-20 ft. below the hydraulic grade-line; the iron is thus compelled to resist a pressure never over 10 lb. to the sq. in., which ordinary stove-pipe iron will generally do. (Von Wagenen.)

WATER: *Ordinary Dimensions of Iron Feed Pipes.*

Diameter of Pipe.	Pressure.	No. of Iron.	Thickness of Iron.
in.	ft.		in.
22	150	16	0.060
22	150 to 250	14	0.078
22	250 to 310	12	0.098
30	150	14	0.078
30	150 to 275	12	0.098
40	160	..	0.236

The iron used varies generally from No. 16 to No. 11, according to the pressure, the best iron only being employed. The size of the pipe will depend upon the supply of water; with 1500-2000 in. of water, a 22-in. pipe will suffice; where the supply is 3000 in., a 30-in. pipe must be used, and so on.

No. 14 iron will resist a pressure of 300 ft. head, or 130 lb. to the sq. in., and an 11-in. pipe of No. 16 iron, a pressure of 500 ft. or 217 lb. to the in. No. 14 iron is 0.083 in. thick, and weighs 3.35 lb. to the sq. ft.; No. 16 is 0.065 in. thick and 2.63 lb. to the ft. Persons having no practical experience generally make their pipes unnecessarily heavy. (Rep. State Mineralogist, California.)

## WATER: Dams and Reservoirs.

Following are useful rules by Von Wagenen:—

1. *Water at Rest transmits Pressure equally in all Directions.*—If a pressure of 100 lb. is exerted on the entire surface of the water in a reservoir whose section is 10 sq. ft., this pressure is transmitted in its entirety not only to the base, but to every 10 sq. ft. of its sides. Thus, if the interior surface of the reservoir (base and sides) measures 250 sq. ft., and a pressure of 100 lb. is placed on the water-surface (of 10 sq. ft.), the base and walls will receive a total pressure of 2500 lb. Or if the box be so closed at the top as to leave but 1 sq. ft. of water exposed, and if a pressure of 100 lb. be applied on this 1 sq. ft., an equal pressure will be transmitted to every sq. ft. of interior surface, and the total will consequently be 25,000 lb. Or, to illustrate this remarkable property still more thoroughly, suppose the top of the vessel to be covered with the exception of 1 sq. in. If on this a pressure of 100 lb. is placed, every sq. in. of interior surface will be pressed outward with this weight, which, for the size box under consideration, would amount altogether to 1800 tons.

2. *The Pressure exerted by Water on the Horizontal Bottom of a Vessel* is wholly independent of the shape of the vessel, and is equal to the weight of a column of water whose base is the area of the horizontal bottom, and whose height is equal to the depth of the liquid.

3. *The Pressure of Water on the sides of a Vessel* is equal to the weight of a column of water whose base is equal to the area of the side, and whose height is equal to one-half the depth of the liquid. Owing to this law, the pressure on the walls and base of a cubical vessel is equal to three times the weight of the water contained.

Referring to the third principle just enunciated, it will be seen that the pressure on any surface under water depends upon two things—the depth of water and the area of the surface pressed. For example, what will be the pressure against the inner slope of a dam 50 ft. long, 12 ft. wide, and 12 ft. deep at the bottom? *Ans.*—Multiply the area of the slope ( $50 \times 12 = 600$ ) by the average vertical depth in ft. of the centre of gravity of the slope (6) = 3600, and multiply this by 62.5 (the weight of 1 cub. ft. of water) = 225,000 lb.

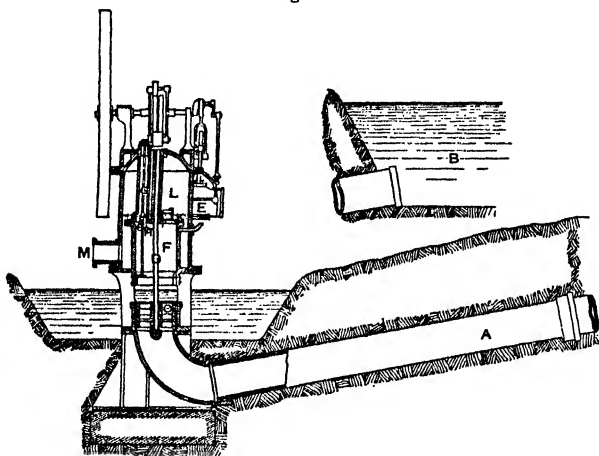
It will be noted that the pressure is no greater if the water reaches back from the face of the dam for miles, than if it were a reservoir only a few ft. broad. Hence, if a reservoir is built simply for storage, make it large and shallow rather than small of area and deep. The loss by solar evaporation will, it is true, be much greater, but this disadvantage will be counterbalanced, first, by the small leakage; second, by the cheapness of the dam; and, third, by the great safety of the construction.

Pearsall's hydraulic engine (Fig. 7) utilises water power for pumping without the intervention of pumps. The flow pipe A

*Water*—continued.

conducts water from the source B to the engine, the water flowing freely through main valve C when open as shown. Rod D moves C up and down at proper intervals by means of motor E. At the period of the engine stroke shown, the chamber F contains only air and communicates freely with the atmosphere by pipe G fitted with float valve J. When C is raised and closed it shuts off the flow of water, but does not check it till *completely* closed, because, until chamber F is filled with water up to float H, valve J remains

Fig. 7.



Pearsall's Hydraulic Engine.

open, giving free communication between chamber F and the atmosphere; consequently the air freely escapes from the chamber and the water freely rises in the chamber. This action takes place *during the closing* of main valve C, consequently no power is wasted in forcing water through the narrowing orifice of this valve, and there is no need to close this valve with great rapidity, and in fact it comes to rest without any concussion. When the water touches float H, it closes valve J, shutting off the passage for escape of air; the pressure in chamber then rises to the point at which valves K open, and some water flows into air vessel L, from which it is constantly flowing out through delivery pipe M. A little air still remains in the chamber at the instant when valve J closes. This air is compressed, enters the air vessel, and is used to drive the motor which actuates the main valve. The column of water in flow pipe is thus brought to rest entirely by elastic resistance of

*r*—continued.

air. When it has ceased to flow, the main valve is again opened, the water with which the chamber F is now full escapes, the air valve J falls open, admitting atmospheric air, and the water again begins to flow and to escape through valve C. The machine in action is exceedingly smooth and regular; and the useful effect is greater than has ever been attained in the application of water-power to raising water. Besides economy, the system has the following incidental advantages. The water may be used with high pressure even at the highest points of ground to be sluiced, and available pressure for hydraulicing is not limited by the topographical features of the country. At the point where the machines are erected, a large extra supply of water is available besides that at high pressure, and greatly helps to keep the tail-flume clear. Efficiency is 70 per cent. A head of water varying from 10 to 40 ft. has been used, and there appears no reason why these machines should not work equally well with heads varying from 2 to 100 ft. They will work with water carrying in suspension large quantities of earth, gravel and stones, floating sticks and chips, and no obstruction is caused. Considerable variation of head and of quantity of supply, even during working, does not affect the efficiency; and if these factors vary inversely at the same time, as they usually do, the quantity and pressure of water pumped remain the same. The air-vessel is very easily charged with air to any required pressure by the direct action of the water.

## TRANSMITTING POWER.

By WIRE ROPE.

Table 21.—Iron Wire Rope, 6-strand, 7 wires. (Stahl.)

Trade No.	Diameter.	Price per ft.	Estimated Weight per ft. in lb.	Breaking Stress, in tons of 2000 lb.	Proper Working Load in tons of 2000 lb.
	in.	s. d.			
11	1½	2 0	3·37	36·0	9
12	1½	1 7½	2·77	30·0	7½
13	1½	1 5	2·28	25·0	6½
14	1½	1 1½	1·82	20·0	5
15	1	0 11½	1·50	16·0	4
16	¾	0 9½	1·12	12·3	3
17	¾	0 7	0·88	8·8	2½
18	¾	0 6	0·70	7·6	2
19	¾	0 5½	0·57	5·8	1½
20	¾	0 4	0·41	4·1	1
21	¾	0 3½	0·31	2·83	¾
22	¾	0 2½	0·23	2·13	¾
23	¾	0 2½	0·19	1·65	
24	¾	0 2	0·16	1·38	
25	¾	0 1½	0·125	1·03	

Table 22.—Special Cast-steel Wire Rope, 6-strand, 7 wires. (Stahl.)

Trade No.	Diameter.	Price per ft.	Estimated Weight per ft. in lb.	Breaking Stress, in tons of 2000 lb.	Proper Working Load in tons of 2000 lb.
	in.	s. d.			
11	1½	2 11	3·37	88·38	22·0
12	1½	2 6	2·77	67·20	16·8
13	1½	2 1	2·28	60·67	15·2
14	1½	1 8	1·82	39·84	10·0
15	1	1 4	1·50	31·82	8·0
16	¾	1 0½	1·12	24·70	6·2
17	¾	0 9½	0·88	18·48	4·6
18	¾	0 8	0·70	16·32	4·0
19	¾	0 7	0·57	12·44	3·1
20	¾	0 5½	0·41	9·33	2·3
21	¾	0 4	0·31	6·89	1·7
22	¾	0 3½	0·28	5·23	1·3
23	¾	0 3½	0·19	3·93	1·0
24	¾	0 2½	0·16	3·25	0·81
25	¾	0 2½	0·125	2·96	0·75

TRANSMITTING POWER: *Ropes.* (Nystrom.)

In the accompanying Tables (23-35) *Column D* contains the minimum diameter of pulley, wheel, or drum that should be used for the maximum diameter of rope in the next column, *d*. The pulley may be made larger for the same size or smaller rope, and the larger the better for the rope. The heading of each column explains the contents.

The wear of a rope is proportionate to its stiffness—that is, as the cube  $d^3$  of its diameter, and inversely as the square  $D^2$  of the diameter of the pulley.

$$\text{Wear of rope} = \frac{d^3}{D^2},$$

*d* = diameter in in. of the rope, and *D* = diameter in ft. of the pulley.

*Column Φ* contains the stiffness of the rope in lb. for both winding and unwinding on each pulley; when the rope runs over a number of pulleys, as when power is transmitted for long distances, the stiffness must be added for each pulley.

The dynamics of transmission of power by belting, ropes, or chains is calculated by the formulas for circular motion.

The circumference of a rope, as practically measured by a tape-line, is not 3·14 times the diameter of the rope, but is considerably less, depending upon the number of strands in the rope.

*d* = diameter and *c* = circumference of the rope.

Two strands	.. ..	$\pi = 2\cdot57.$	$c = 2\cdot57 d.$
			$d = 0\cdot389 c.$
Three strands	.. ..	$\pi = 2\cdot86.$	$c = 2\cdot86 d.$
			$d = 0\cdot35 c.$
Four strands	.. ..	$\pi = 2\cdot96.$	$c = 2\cdot96 d.$
			$d = 0\cdot338 c.$
Seven strands	.. ..	$\pi = 3.$	$c = 3 d.$

The diameter of the rope is that of the circle tangenting the strands, whilst the circumference is the sum of the lines drawn between the strands.

The accompanying Tables (23-35) were deduced from experiments specially made by Nystrom for his well-known 'Mechanical Engineers' Pocket-book.'

Table 23.—TRANSMITTING POWER: Horse-power of Iron and Steel Ropes.

Iron. Diam.	Velocity of Rope in ft. per Second.								Steel. Diam.
	10	20	30	40	50	60	70	80	
in.	H.P.	H.P.	H.P.	H.P.	H.P.	H.P.	H.P.	H.P.	H.P.
$\frac{1}{4}$	4	8	12	16	20	24	28	32	$\frac{3}{16}$
$\frac{5}{16}$	6	12	18	25	31	37	43	50	$\frac{1}{4}$
$\frac{3}{8}$	9	18	27	36	45	54	63	72	$\frac{5}{16}$
$\frac{7}{16}$	12	24	36	49	61	73	85	98	$\frac{3}{8}$
$\frac{1}{2}$	16	32	48	64	80	96	112	128	$\frac{7}{16}$
$\frac{9}{16}$	20	40	60	81	101	121	141	162	$\frac{1}{2}$
$\frac{5}{8}$	25	50	75	100	125	150	175	200	$\frac{9}{16}$
$\frac{3}{4}$	30	60	90	121	151	181	211	242	$\frac{5}{8}$
$\frac{7}{8}$	36	72	108	144	180	216	252	288	$\frac{3}{4}$
$1\frac{1}{8}$	42	84	126	169	211	253	295	338	$1\frac{1}{8}$
$1\frac{1}{4}$	49	98	147	196	245	294	343	392	$1\frac{1}{4}$
$1\frac{3}{8}$	56	112	168	225	281	337	393	450	$1\frac{3}{8}$
$1\frac{1}{2}$	64	128	192	256	320	384	448	512	$1\frac{1}{2}$
$1\frac{5}{8}$	81	162	243	324	405	486	567	648	$1\frac{5}{8}$
$1\frac{3}{4}$	100	200	300	400	500	600	700	800	$1\frac{3}{4}$
$1\frac{7}{8}$	121	242	363	484	605	726	847	968	$1\frac{7}{8}$
$2$	144	288	432	576	720	864	1008	1152	$2$
$2\frac{1}{8}$	169	338	507	676	845	1014	1183	1352	$2\frac{1}{8}$
$2\frac{1}{4}$	196	392	588	784	980	1176	1372	1568	$2\frac{1}{4}$
$2\frac{3}{8}$	225	450	675	900	1125	1350	1575	1800	$2\frac{3}{8}$
$2\frac{1}{2}$	256	512	768	1024	1280	1536	1792	2048	$2\frac{1}{2}$
$2\frac{5}{8}$	324	648	971	1296	1620	1944	2268	2602	$2\frac{5}{8}$
$2\frac{3}{4}$	400	800	1200	1600	2000	2400	2800	3200	$2\frac{3}{4}$
$2\frac{7}{8}$	484	968	1452	1936	2420	2904	3388	3872	$2\frac{7}{8}$
3	576	1152	1728	2304	2880	3456	4032	4608	3

Table 24.—TRANSMITTING POWER: *Hemp Rope, white, 3 strands.*

Diam. Pulley. ft.	Size of Rope.		Strength.		Weight per ft. lb.	Length per lb. ft.	Stiffness.	
	Diam. in.	Circum. in.	Break. lb.	Safety. lb.			Winding.	Wind and Unwind.
D	d	c	S	T	w	l	Φ	Φ
21.0	6	17.1	324,000	81,000	9.4	.1064	7.6	12.7
19.0	5½	15.7	272,000	68,000	7.9	.1266	6.6	11.0
16.5	5	14.25	225,000	56,250	6.52	.1533	6.0	10.0
14.0	4½	12.1	182,000	45,500	5.28	.1894	5.4	9.0
12.0	4	11.4	144,000	36,000	4.18	.2392	4.6	7.7
11.0	3½	10.7	126,000	31,500	3.67	.2725	4.2	7.0
10.0	3¼	10.0	110,000	27,500	3.2	.3125	3.9	6.5
9.0	3¼	9.27	95,000	23,750	2.76	.3613	3.6	6.0
8.0	3	8.57	81,000	20,250	2.35	.4255	3.36	5.6
7.0	2½	7.85	68,000	17,000	1.97	.5076	3.05	5.1
6.0	2½	7.14	56,200	14,050	1.63	.6135	2.82	4.7
5.25	2¼	6.43	45,500	11,375	1.32	.7575	2.4	4.0
4.25	2	5.70	36,000	9,000	1.04	.9615	2.25	3.75
3.4	1½	5.00	27,500	6,875	0.80	1.25	2.1	3.5
2.75	1½	4.23	20,200	5,050	0.588	1.700	1.74	2.9
2.1	1¼	3.97	14,000	3,500	0.407	2.457	1.44	2.4
1.5	1	2.86	9,000	2,250	0.261	3.831	1.16	1.93
1.22	¾	2.5	6,900	1,725	0.200	5.000	1.02	1.7
0.97	¾	2.14	5,050	1,262	0.147	6.803	0.87	1.46
0.74	¾	1.78	3,500	875	0.102	9.803	0.72	1.21
0.53	¾	1.43	2,240	560	0.065	15.38	0.58	0.97
0.34	¾	1.07	1,260	315	0.036	27.77	0.45	0.75
0.18	¾	0.71	560	140	0.016	62.50	0.31	0.52



Table 25.—TRANSMITTING POWER: Manila Ropes, 3 strands.

Diam. Pulley. ft.	Size of Rope.		Strength.		Weight per ft. lb.	Length per lb. ft.	Stiffness.	
	Diam. in.	Circum. in.	Break. lb.	Safety. lb.			Winding.	Wind and Unwind.
	<i>d</i>	<i>c</i>	<i>S</i>	<i>T</i>	<i>w</i>	<i>l</i>	$\Phi$	$\Phi$
D								
26.4	6	17.1	216,000	54,000	8.64	.1157	5.37	8.87
23.2	5½	15.7	181,500	45,375	7.26	.1377	5.00	8.26
20.0	5	14.25	150,000	37,500	6.00	.1666	4.5	7.45
17.2	4½	12.1	121,000	30,250	4.86	.2057	4.00	6.62
14.4	4	11.4	96,000	24,000	3.84	.2604	3.57	5.9
13.0	3¾	10.7	84,400	21,100	3.38	.2958	3.37	5.66
11.8	3½	10.0	73,600	18,400	2.94	.3401	3.10	5.15
10.5	3¼	9.27	63,500	15,875	2.53	.3952	2.93	4.85
9.35	3	8.57	54,000	13,500	2.16	.4629	2.68	4.43
8.2	2¾	7.85	45,400	11,350	1.81	.5524	2.45	4.06
7.1	2½	7.14	37,500	9,375	1.5	.6666	2.24	3.70
6.0	2¼	6.43	30,400	7,600	1.21	.8264	2.06	3.4
5.0	2	5.70	24,000	6,000	0.96	1.041	1.85	3.07
4.0	1½	5.00	18,400	4,600	0.725	1.379	1.700	2.8
3.3	1¼	4.28	13,500	3,350	0.54	1.852	1.40	2.32
2.5	1½	3.57	9,380	2,345	0.375	2.666	1.11	1.84
1.8	1	2.86	6,000	1,500	0.24	4.166	0.8870	1.47
1.46	¾	2.5	4,600	1,150	0.184	5.435	0.894	1.31
1.17	¾	2.14	3,380	845	0.135	7.407	0.6666	1.10
0.89	½	1.78	2,350	587	0.093	10.75	0.558	0.92
0.63	½	1.43	1,500	375	0.060	16.66	0.454	0.75
0.41	½	1.07	845	211	0.033	30.30	0.38	0.56
0.23	½	0.71	375	93	0.015	66.66	0.23	0.38

Table 26.—TRANSMITTING POWER: *Tarred Hemp Ropes, 4 strands.*

Diam. Pulley, ft.	Size of Rope.		Strength.		Weight per ft., lb.	Length per lb., ft.	Stiffness.	
	Diam. in.	Circum. in.	Break. lb.	Safety. lb.			Winding. $\Phi$	Wind and Unwind. $\Phi$
D	d	c	S	T	w	l	$\Phi$	$\Phi$
36.0	6	18	230,000	57,500	15.1	.0662	13.3	13.9
32.0	5½	16½	194,000	48,500	12.7	.0784	12.0	17.0
28.0	5	15	160,000	40,000	10.5	.0952	10.6	15.1
24.0	4½	13½	130,000	32,500	8.52	.1174	9.5	13.5
20.0	4	12	102,500	25,625	6.72	.1488	8.5	12.1
18.0	3½	11½	90,000	22,500	5.92	.1689	8.1	11.5
16.0	3¼	10¾	78,500	19,625	5.16	.1938	7.8	11.1
14.6	3¼	9¾	67,700	16,925	4.44	.2252	7.0	10.0
12.9	3	9	57,700	14,425	3.78	.2645	6.46	9.2
11.4	2½	8½	48,400	12,100	3.18	.3144	5.83	8.3
9.9	2½	7½	40,000	10,000	2.63	.3802	5.27	7.5
8.4	2½	6½	32,400	8,100	2.13	.4695	4.83	6.87
7.0	2	6	25,600	6,400	1.68	.5952	4.34	6.18
5.8	1½	5½	19,600	4,900	1.29	.7752	3.70	5.26
4.6	1½	4½	14,400	3,600	0.945	1.058	3.18	4.53
3.5	1½	3½	10,000	2,500	0.656	1.524	2.64	3.76
2.5	1	3	6,400	1,600	0.420	2.381	2.13	3.03
2.0	¾	2½	4,900	1,225	0.322	3.105	1.95	2.78
1.6	¾	2¼	3,600	900	0.236	4.237	1.64	2.34
1.2	¾	1¾	2,500	625	0.164	6.097	1.40	2.00
0.9	¾	1¾	1,600	400	0.105	9.523	1.02	1.46
0.68	¾	1¼	900	225	0.059	16.95	0.77	1.10
0.31	¾	¾	400	100	0.026	38.46	0.53	0.76

Table 27.—TRANSMITTING POWER: Cotton Ropes, 3 strands of Fine Yarns.

Diam. Pulley. ft.	Size of Rope.		Strength.		Weight per ft. lb.	Length per lb. ft.	Stiffness.	
	Diam. in.	Circum. in.	Break. lb.	Safety. lb.			Winding.	Wind and Unwind.
D	d	c	S	T	w	l	$\Phi$	$\Phi$
14.7	6	18	18,000	4,500	7.20	0.1389	4.0	6.0
12.9	5½	16½	15,125	3,781	6.05	0.1653	3.68	5.5
11.2	5	15	12,500	3,125	5.00	0.2000	3.3	5.0
9.5	4½	13½	10,125	2,531	4.05	0.2469	3.0	4.5
8.0	4	12	8,000	2,000	3.20	0.3125	2.66	4.0
7.2	3¾	11¾	7,030	1,782	2.81	0.3559	2.55	3.83
6.5	3½	10½	6,125	1,531	2.45	0.4082	2.37	3.56
5.8	3¼	9¾	5,281	1,320	2.11	0.4739	2.23	3.33
5.2	3	9	4,500	1,125	1.80	0.5555	2.0	3.0
4.5	2¾	8¾	3,781	945	1.52	0.6579	1.89	2.84
4.0	2½	7½	3,125	781	1.25	0.8000	1.63	2.45
3.4	2¼	6¾	2,531	633	1.01	0.9901	1.48	2.23
2.8	2	6	2,000	500	0.80	1.250	1.36	2.05
2.3	1½	5½	1,531	383	0.61	1.639	1.18	1.78
1.8	1¼	4¾	1,125	281	0.45	2.222	1.04	1.58
1.4	1¼	3¾	781	195	0.31	3.226	0.83	1.25
1.0	1	3	500	125	0.20	5.000	0.66	1.0
0.82	¾	2¾	383	96	0.15	6.666	0.59	0.89
0.65	¾	2¼	281	70	0.11	9.009	0.5	0.75
0.5	¾	1¾	195	49	0.078	12.82	0.4	0.61
0.35	¾	1¼	125	31	0.05	20.00	0.34	0.51
0.23	¾	1¼	70	17	0.028	35.71	0.25	0.37
0.125	¾	¾	31	8	0.012	83.33	0.16	0.25

Table 28.—TRANSMITTING POWER: *Iron Ropes. 19 X 7 = 133 Wires and Wire Centre.*

Diam. Pulley. ft.	Size of Rope.		Strength.		Weight per ft. lb.	Length per lb. ft.	Stiffness.	
	Diam. in.	Circum. in.	Break. lb.	Safety. lb.			Winding.	Wind and Unwind.
	$d$	$c$	S	T	$w$	$l$	$\Phi$	$\Phi$
D	3	9	300,000	75,000	16.83	.0594	5.4	7.4
41.6	2½	8½	252,500	63,125	12.45	.0803	4.95	6.8
36.5	2½	7½	209,000	51,250	10.3	.0971	4.54	6.24
31.5	2½	6½	169,000	42,250	8.34	.1199	4.06	5.58
27.0	2	6	133,000	33,250	6.82	.1510	3.60	4.97
22.6	2	5½	117,500	29,375	5.78	.1730	3.37	4.64
20.5	1½	5	102,000	25,500	5.04	.1984	3.15	4.34
18.5	1½	4½	88,400	21,100	4.35	.2299	2.95	4.05
16.5	1½	4	75,200	18,800	3.70	.2703	2.65	3.64
14.75	1½	4	63,200	15,800	3.12	.3205	2.42	3.33
13.0	1½	3½	52,200	13,050	2.57	.3891	2.22	3.06
11.2	1½	3½	42,300	10,575	2.08	.4807	1.91	2.77
9.55	1½	3	33,300	8,325	1.65	.6061	1.80	2.47
8.0	1	2½	25,600	6,400	1.26	.7936	1.56	2.15
6.56	1	2½	18,800	4,700	.927	1.078	1.34	1.85
5.2	¾	2	13,000	3,250	0.644	1.553	1.11	1.54
3.96	¾	1½	8,360	2,090	0.412	2.427	0.90	1.23
2.83	¾	1½	6,400	1,600	0.315	3.174	0.79	1.09
2.31	¾	1½	4,710	1,177	0.231	4.329	0.68	0.93
1.83	¾	1½	2,270	812	0.160	6.250	0.55	0.76
1.4	¾	1½	2,090	522	0.102	9.804	0.44	0.61
1.0	¾	1½	1,180	295	0.057	17.54	0.33	0.46
0.65	¾	1½	522	130	0.025	40.00	0.23	0.32
0.35	¾	1½						

Table 29.—TRANSMITTING POWER: *Iron Ropes. 19 × 6 = 114 Wires and Hemp Centre.*

Diam. Pulley. ft.	Size of Rope.		Strength.		Weight per ft. lb.	Length per ft. ft.	Stiffness.	
	Diam. in.	Circum. in.	Break. lb.	Safety. lb.			Winding.	Wind and Unwind.
D	$d$	$c$	$S$	$T$	$w$	$l$	$\Phi$	$\Phi$
31.0	3	9	287,500	71,875	13.5	.0741	7.2	10.1
27.0	2½	8½	241,500	60,375	11.3	.0885	6.77	9.46
23.7	2¼	7¾	200,000	50,000	9.36	.1068	6.09	8.51
20.0	2¼	6¾	161,500	40,750	7.60	.1316	5.51	7.71
17.0	2	6	128,000	32,000	6.02	.1661	4.75	6.65
15.4	1¾	5½	112,000	28,000	5.27	.1807	4.47	6.25
14.0	1¾	5¼	98,000	24,500	4.58	.2183	4.11	5.75
12.4	1½	4¾	84,400	21,100	3.96	.2525	3.90	5.45
11.0	1½	4½	72,000	18,000	3.37	.2967	3.66	5.12
9.7	1½	4¼	60,400	15,100	2.83	.3533	3.25	4.55
7.8	1¼	3¾	50,000	12,500	2.34	.4273	2.96	4.13
7.1	1¼	3½	40,400	10,100	1.89	.5291	2.73	3.82
6.0	1	3	32,000	8,000	1.50	.6666	2.39	3.34
5.0	¾	2½	24,350	6,082	1.14	.8772	2.00	2.81
4.0	¾	2¼	18,000	4,500	0.844	1.184	1.70	2.38
3.0	¾	1¾	12,500	3,125	0.586	1.706	1.45	2.03
2.1	¾	1½	8,000	2,000	0.375	2.686	1.22	1.70
1.7	½	1¼	6,120	1,530	0.287	3.484	1.09	1.52
1.3	½	1¼	4,500	1,125	0.211	4.739	1.01	1.41
1.0	½	1¼	3,129	780	0.146	6.819	0.81	1.14
0.75	¾	1½	2,000	500	0.093	10.75	0.59	0.83
0.5	¾	1½	1,120	280	0.052	19.23	0.42	0.60
0.27	¾	1½	500	125	0.023	43.48	0.29	0.41

Table 30.—TRANSMITTING POWER: *Iron Ropes. 7 × 7 = 49 Wires and Wire Centre.*

Diam. Pulley. ft.	Size of Rope.		Strength.		Weight per ft. lb.	Length per lb. ft.	Stiffness.	
	Diam. in.	Circum. in.	Break. lb.	Safety. lb.			Winding.	Wind and Unwind.
D	d	c	S	T	w	l	Φ	Φ
62.5	3	9	300,000	75,000	16.83	.0594	8.8	12.1
54.5	2½	8½	252,500	63,125	12.45	.0803	7.9	10.9
47.0	2¼	7¾	209,000	51,250	10.3	.0871	7.45	10.2
40.0	2¼	6¾	169,000	42,250	8.34	.1199	6.8	9.30
34.0	2	6	133,000	33,250	6.62	.1510	5.86	8.04
30.0	1¾	5½	117,500	29,375	5.78	.1730	5.60	7.68
27.0	1¾	5¼	102,000	25,500	5.04	.1984	5.30	7.26
25.0	1¾	4¾	88,400	44,100	4.35	.2239	4.72	6.48
22.0	1½	4½	75,200	19,800	3.70	.2703	4.41	6.05
19.0	1½	4¼	63,200	15,800	3.12	.3205	4.18	5.74
16.5	1¼	3¾	52,200	18,050	2.57	.3891	3.78	5.19
14.0	1¼	3½	42,300	10,575	2.08	.4807	3.45	4.74
12.0	1	3	33,300	8,325	1.65	.6061	2.93	4.03
10.0	¾	2½	25,600	6,400	1.26	.7936	2.48	3.40
8.0	¾	2¼	18,900	4,700	0.927	1.078	2.05	2.82
6.0	¾	1¾	13,000	3,250	0.644	1.553	1.79	2.46
4.25	¾	1½	8,360	2,090	0.412	2.427	1.53	2.10
3.5	½	1½	6,400	1,600	0.315	3.174	1.26	1.73
2.75	½	1¼	4,710	1,177	0.231	4.329	1.10	1.52
2.1	½	1¼	3,270	812	0.160	6.250	0.91	1.25
1.5	¾	1¼	2,090	522	0.102	9.804	0.73	1.00
1.0	¾	1¼	1,180	295	0.057	17.54	0.52	0.72
0.5	¾	1¼	522	130	0.025	40.00	0.4	0.56

Table 31.—TRANSMITTING POWER: *Iron Ropes. 7 × 6 = 42 Wires and Hemp Centre.*

Diam. Pulley. ft.	Size of Rope.		Strength.		Weight per ft. lb.	Length per ft. ft.	Stiffness.	
	Diam. in.	Circum. in.	Break. lb.	Safety. lb.			Winding.	Wind and Unwind.
D	d	c	S	T	w	l	Φ	Φ
52.0	3	9	287,500	71,875	13.5	.0741	5.00	7.02
45.0	2½	8½	241,500	60,375	11.3	.0885	4.72	6.62
39.0	2½	7½	200,000	50,000	9.36	.1063	4.26	6.00
34.0	2½	6½	161,500	40,750	7.60	.1316	3.72	5.21
28.0	2	6	128,000	32,000	6.02	.1661	3.43	4.81
25.0	1½	5½	112,000	28,000	5.27	.1807	3.17	4.44
23.0	1½	5½	98,000	24,500	4.58	.2183	2.93	4.12
21.0	1½	4½	84,400	21,100	3.96	.2525	2.64	3.70
18.0	1½	4½	72,000	18,000	3.37	.2967	2.5	3.49
16.0	1½	4½	60,400	15,100	2.83	.3533	2.33	3.27
14.0	1½	3½	50,000	12,500	2.34	.4273	2.10	2.95
12.0	1½	3½	40,400	10,100	1.89	.5291	1.85	2.60
10.0	1	3	32,000	8,000	1.50	.6666	1.60	2.34
8.2	¾	2½	24,250	6,062	1.14	.8772	1.45	2.04
6.5	¾	2½	18,000	4,500	0.844	1.184	1.25	1.75
5.0	¾	1½	12,500	3,125	0.586	1.706	1.02	1.43
3.5	¾	1½	8,000	2,000	0.375	2.666	0.85	1.20
3.0	¾	1½	6,120	1,530	0.287	3.484	0.67	0.95
2.3	¾	1½	4,500	1,125	0.211	4.739	0.62	0.87
1.7	¾	1½	3,120	780	0.146	6.849	0.55	0.77
1.25	¾	1½	2,000	500	0.093	10.75	0.41	0.58
0.8	¾	1½	1,120	280	0.052	19.23	0.32	0.45
0.4	¾	1½	500	125	0.023	43.48	0.25	0.35

Table 32.—TRANSMITTING POWER: *Iron Rope, 7 × 6 × 6 = 252 Wires. Cotton Centre in each Rope Strand and Hemp in the Centre.*

Diam. Pulley. ft.	Size of Rope.		Strength.		Weight per ft. lb.	Length per lb. ft.	Stiffness.	
	Diam. in.	Circum. in.	Break. lb.	Safety. lb.			Winding.	Wind and Unwind.
	<i>d</i>	<i>c</i>	<i>S</i>	<i>T</i>	<i>w</i>	<i>l</i>	<i>Φ</i>	<i>Φ</i>
D								
21.0	3	9	270,000	67,500	12.2	.0819	5.40	7.80
18.0	2½	8½	226,500	56,625	10.2	.0980	4.88	7.04
16.0	2¼	7¾	187,000	46,750	8.57	.1167	4.40	6.37
13.5	2¼	6¾	152,000	38,000	6.84	.1462	3.98	5.74
11.0	2	6	120,000	30,000	5.42	.1845	3.74	5.39
10.0	1¾	5½	105,400	26,350	4.76	.2101	3.50	5.03
9.0	1¼	5¼	91,700	22,925	4.13	.2421	3.26	4.70
8.0	1¼	4¾	79,000	19,750	3.66	.2809	3.08	4.44
7.0	1¼	4¼	67,500	16,875	3.04	.3289	2.87	4.14
6.25	1¼	4¼	56,600	14,250	2.55	.3921	2.58	3.72
5.5	1¼	3¾	46,800	11,700	2.11	.4739	2.30	3.30
4.75	1¼	3¼	38,000	9,500	1.71	.5848	2.00	2.90
4.0	1	3	30,000	7,500	1.35	.7407	1.77	2.55
3.25	¾	2½	23,000	5,750	1.03	.9709	1.57	2.27
2.6	¾	2¼	16,850	4,212	0.760	1.316	1.32	1.91
2.0	¾	1¾	11,700	2,925	0.528	1.894	1.09	1.57
1.4	¾	1¼	7,500	1,875	0.334	2.958	0.90	1.30
1.15	¾	1¼	5,740	1,435	0.258	3.876	0.79	1.14
0.9	¾	1¼	4,220	1,055	0.190	5.263	0.69	1.00
0.7	¾	1¼	2,930	732	0.132	7.576	0.55	0.80
0.5	¾	1¼	1,870	467	0.084	11.90	0.44	0.64
0.3	¾	1¼	1,050	262	0.047	21.27	0.38	0.56
0.18	¾	1¼	468	117	0.021	47.62	0.20	0.30



Table 33.—TRANSMITTING POWER: Cast Steel Ropes.  $19 \times 7 = 133$  Wires and Wire Centre.

Diam. Pulley. ft.	Size of Rope.		Strength.		Weight per ft. lb.	Length per lb. ft.	Stiffness.	
	Diam. in.	Circum. in.	Break. lb.	Safety. lb.			Winding.	Wind and Unwind.
D	$d$	$c$	S	T	$w$	$l$	$\Phi$	$\Phi$
50.0	3	9	486,000	121,500	16.33	.0594	9.37	11.7
45.0	2½	8½	416,000	104,000	12.45	.0803	8.19	10.2
38.7	2½	7½	344,000	86,000	10.3	.0971	7.59	9.45
33.0	2½	6½	279,000	69,750	8.34	.1199	6.84	8.52
27.7	2	6	220,000	55,000	6.62	.1510	6.36	7.92
25.0	1½	5½	183,500	48,375	5.78	.1730	5.73	7.15
22.7	1½	5½	168,500	42,125	5.04	.1984	5.28	6.58
20.3	1½	4½	145,500	36,375	4.35	.2299	4.87	6.08
18.0	1½	4½	123,500	30,875	3.70	.2703	4.52	5.63
15.8	1½	4½	104,000	26,000	3.12	.3203	4.12	5.13
13.7	1½	3½	86,000	21,500	2.57	.3891	3.77	4.70
11.7	1½	3½	69,600	17,400	2.08	.4807	3.39	4.23
9.8	1	3	55,000	13,750	1.65	.6061	3.00	3.75
8.0	¾	2½	42,200	10,550	1.26	.7936	2.65	3.30
6.4	¾	2½	31,000	7,750	0.927	1.078	2.24	2.79
4.87	¾	1½	21,500	5,375	0.614	1.553	1.87	2.33
3.46	¾	1½	13,750	3,687	0.412	2.427	1.51	1.89
2.84	½	1½	10,500	2,625	0.315	3.174	1.32	1.65
2.25	½	1½	7,740	1,935	0.231	4.329	1.13	1.41
1.71	½	¾	5,380	1,345	0.160	6.250	0.94	1.18
1.22	¼	¾	3,440	860	0.102	9.504	0.75	0.94
0.8	¼	¾	1,935	484	0.057	17.54	0.56	0.70
0.433	¼	¾	860	215	0.025	40.00	0.38	0.48

Table 34.—TRANSMITTING POWER: Cast Steel Ropes. 19 X 6 = 114 Wires and Hemp Centre.

Diam. Pulley. ft.	Size of Rope.		Strength.		Weight per ft. lb.	Length per ft. ft.	Stiffness.	
	Diam. in.	Circum. in.	Break. lb.	Safety. lb.			Winding.	Wind and Unwind.
D	$d$	$c$	$S$	$T$	$w$	$l$	$\Phi$	$\Phi$
41.6	3	9	432,000	108,000	13.5	.0741	6.0	8.25
36.5	2½	8½	363,000	90,750	11.3	.0885	5.45	7.50
31.5	2¼	7½	300,000	75,000	9.36	.1068	5.04	6.93
27.0	2½	6½	243,000	67,500	7.60	.1316	4.51	6.20
22.6	2	6	192,000	48,000	6.02	.1661	4.00	5.49
20.5	1½	5½	168,500	42,125	5.27	.1807	3.77	5.18
18.5	1½	4½	146,500	36,625	5.08	.2183	3.50	4.82
16.5	1½	4½	126,500	31,625	3.96	.2525	3.27	4.50
14.75	1½	4½	108,000	27,000	3.37	.2967	2.98	4.10
13.0	1½	4½	90,700	22,675	2.83	.3533	2.70	3.72
11.2	1½	3½	75,000	18,750	2.34	.4273	2.50	3.43
9.55	1½	3½	60,700	15,175	1.89	.5291	2.24	3.08
8.0	1	3	48,000	12,000	1.50	.6866	2.00	2.76
6.56	1	2½	36,800	9,200	1.14	.8772	1.74	2.40
5.2	¾	2½	27,000	6,750	0.844	1.184	1.50	2.06
3.96	¾	1½	18,750	4,687	0.586	1.706	1.24	1.71
2.83	¾	1½	12,000	3,000	0.375	2.686	1.00	1.38
2.31	¾	1½	9,200	2,300	0.287	3.484	0.88	1.21
1.83	¾	1½	6,750	1,687	0.211	4.739	0.75	1.04
1.4	¾	1½	4,680	1,170	0.146	6.849	0.61	0.85
1.0	¾	1½	3,000	750	0.093	10.75	0.49	0.68
0.65	¾	1½	1,685	421	0.052	19.23	0.37	0.51
0.35	¾	1½	750	187	0.023	43.48	0.24	0.33

Table 35.—TRANSMITTING POWER: Copper Ropes. 7 × 6 = 42 Wires. Cotton Centre.

Diam. Pulley. ft.	Size of Rope.		Strength.		Weight per ft. lb.	Length per lb. ft.	Stiffness.	
	Diam. in.	Circum. in.	Break. lb.	Safety. lb.			Winding. Φ	Wind and Unwind. Φ
D					w	l		Φ
26 0	3	9	306,000	76,500	15.25	.0656	9.60	13.4
22.5	2½	8½	257,000	64,250	12.9	.0775	9.00	12.6
20.0	2¼	7½	212,500	53,125	10.6	.0943	8.50	11.9
17.0	2¼	6½	172,000	43,000	8.44	.1185	7.14	10.0
14.0	2	6	136,100	34,000	6.82	.1466	6.44	9.0
12.5	1½	5½	120,000	30,000	5.97	.1675	6.16	8.6
11.5	1½	5¼	104,000	26,000	5.20	.1923	5.43	7.8
10.5	1½	4½	90,000	22,500	4.48	.2232	5.00	7.0
9.0	1¼	4¼	76,500	19,125	3.82	.2618	4.70	6.1
8.0	1¼	4¼	64,200	16,050	3.21	.3115	4.44	5.70
7.0	1¼	3¾	53,100	13,275	2.86	.3472	3.96	5.30
6.0	1¼	3¾	42,800	10,700	2.15	.4651	3.50	4.90
5.0	1	3	34,000	8,500	1.70	.5882	3.22	4.50
4.0	¾	2½	26,000	6,500	1.30	.7692	2.94	4.10
3.25	¾	2¼	19,100	4,775	0.956	1.046	2.44	3.42
2.5	¾	1¾	13,250	3,312	0.673	1.486	1.83	2.70
1.75	¾	1½	8,500	2,125	0.424	2.358	1.65	2.30
1.5	¾	1½	6,510	1,627	0.325	3.077	1.29	1.80
1.15	¾	1¼	4,780	1,195	0.239	4.184	1.20	1.67
0.85	¾	1¼	3,320	830	0.166	6.024	1.05	1.47
0.62	¾	1¼	2,120	530	0.106	9.433	0.81	1.13
0.4	¾	1¼	1,200	300	0.059	16.95	0.62	0.87
0.2	¾	1¼	530	132	0.026	38.46	0.48	0.67

## ROPE DRIVING. (C. W. Hunt.)

It has been found that 200 lb. on a 1-in. rope is a safe and economical working load, and when materially increased the wear is rapid. Test pieces of manilla rope made at different works varied slightly in diameter, but when reduced to the equivalent of 1 in. diameter had an average breaking strength of 7140 lb. Expressed algebraically, the breaking strength, weight per foot, and the working strains are—

$$W = 720 C^2 (1); P = .32 C^2 (2); w = 20 C^2 (1)$$

In these and the following equations:—

C = circumference of rope in inches.	S = load in lb. on rope at pulley.
D = sag of the rope in inches.	T = tension in lb. on driving side of the rope.
F = centrifugal force in lb.	t = tension in lb. on slack side of the rope.
g = gravity.	v = velocity of rope in ft. per second.
H = horse-power.	w = working load in lb.
L = distance between pulleys in ft.	W = ultimate breaking load in lb.
P = lb. per ft. of rope.	
R = force in lb. doing useful work.	

This makes the normal working load equal to  $\frac{1}{36}$  the breaking strength, and about  $\frac{1}{25}$  of the strength at the splice. The actual loads are ordinarily much greater, owing to the vibrations in running, as well as from imperfectly adjusted tension mechanism.

Assuming that the load on the driving side of a rope is equal to 200 lb. on a rope 1 in. diam., and that the rope is in motion at various velocities of 10 ft. to 140 ft. per second. Then we will have in all cases a fibre load of 200 lb. on the driving side of a 1-in. rope, and an equivalent load for other sizes. The centrifugal force of the rope in running over the pulley will reduce the amount of force available for the transmission of power. The centrifugal force of the rope is computed by the formula—

$$F = \frac{P v^2}{g}. \quad (2)$$

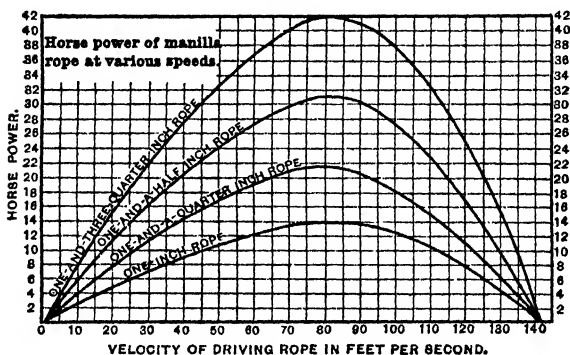
At a speed of about 80 ft. per second, the centrifugal force increases faster than the power from increased velocity of the rope, and about 140 ft. per second equals the assumed allowable tension of the rope. Computing this force at various speeds and then subtracting it from the assumed maximum tension, we have the force available for the transmission of power. The whole of this force

*Rope driving—continued.*

cannot be used, because a certain amount of tension on the slack side of the rope is needed to give adhesion to the pulley. What tension should be given to the rope for this purpose is uncertain, as there are no experiments which give accurate data, and at the present time a decision must be made partly from analogy and partly from experience.

If the rope be considered as a belt on a plain pulley, the friction would be substantially the same as a leather belt at the same tension; but as ropes are frequently lubricated to reduce the wear,

Fig. 8.



the coefficient of friction must be materially reduced. There have been no experiments to decide with accuracy what this reduction is, but it is known from considerable experience that when the rope runs in a groove whose sides are inclined towards each other at an angle of  $45^\circ$  there is sufficient adhesion when the ratio of the tension is

$$\frac{T}{t} = 2. \quad (3)$$

For the present purpose  $T$  can be divided into three parts:—Tension doing useful work, tension from centrifugal force, tension to balance the strain for adhesion. The tension  $t$  can be divided into two parts:—Tension for adhesion, tension from centrifugal force. It is evident, however, that the tension required to do a given work should not be materially exceeded during the life of the rope.

*Rope driving*—continued.

There are two methods of putting ropes on the pulleys; one in which the ropes are single and spliced on, being made very taut at first, and less so as the rope lengthens, stretching until it slips; when it is respliced. The other method is to wind a single rope over the pulley as many turns as needed to obtain the necessary horse-power, and put a tension pulley to give the necessary adhesion and also to take up the wear. The total tension  $T$  on the driving side of the rope is assumed to be the same at all speeds. The centrifugal force, as well as an amount equal to the tension for adhesion on the slack side of the rope, must be taken from the total tension  $T$  to ascertain the amount of force available for the transmission of power.

It is assumed that the tension on the slack side necessary for giving adhesion is equal to one-half the force doing useful work on the driving side of the rope; hence the force for useful work is—

$$R = \frac{2(T-F)}{3}, \quad (4)$$

and the tension on the slack side to give the required adhesion is—

$$\frac{(T-F)}{3}. \quad (5)$$

Hence, 
$$t = \frac{(T-F)}{3} + F. \quad (6)$$

The sum of the tensions  $T$  and  $t$  is not the same at different speeds, as the equation (6) indicates.

As  $F$  varies as the square of the velocity, there is, with an increasing speed of the rope, a decreasing useful force, and an increasing total tension  $t$  on the slack side. With these assumptions of allowable stresses, the horse-power will be—

$$H = \frac{2v(T-F)}{3 \times 550}, \quad (7)$$

Transmission ropes are usually 1-1½ in. diam. A computation of the horse-power for four sizes at various speeds and under ordinary conditions, based on a maximum load equivalent to 200 lb. for a rope 1 in. diam., is given in Fig. 8. The horse-power of other sizes is readily obtained from these. The maximum power is transmitted, under the assumed conditions, at a speed of about 80 ft. per second.

*Rope driving*—continued.

The first cost of the rope will be smallest when the power transmitted by it is greatest, and, under the assumed conditions, will be a minimum for a given power when the velocity of the rope is about 80 ft. per second. The ratio of the first cost of the rope running at any other speed will be—

$$\text{Ratio of first cost} = \frac{H \text{ at 80 ft. per second}}{H \text{ at required speed}}. \quad (8)$$

The wear of the rope is both internal and external; the internal is caused by the movement of the fibres on each other, under pressure in bending over the sheaves, and the external is caused by the slipping and the wedging in the grooves of the pulley. Both of these causes of wear are, within the limits of ordinary practice, assumed to be directly proportional to the speed. Hence, if we assume the coefficient of the wear to be  $k$ , the wear will be  $k v$ , in which the wear increases directly as the velocity, but the horse-power that can be transmitted, as equation (7) shows, will not vary at the same rate.

If we divide the value for wear at a given speed by the horse-power that the same rope will transmit at other speeds, we get the relative wear of the rope in transmitting 1 horse-power. The higher the speed, up to about 80 ft. per second, the more power will be transmitted, but it is accompanied by a more than equivalent wear.

The rope is supposed to have the strain  $T$  constant at all speeds on the driving side, and in direct proportion to the area of the cross-section; hence the catenary of the driving side is not affected by the speed or by the diameter of the rope.

The deflection of the rope between the pulleys on the slack side varies with each change of the load or change of the speed, as the tension equation (8) indicates. The deflection or sag of the rope may be computed for the assumed value of  $T$  and  $t$  by the parabolic formula—

$$S = \frac{P L^2}{8 D} + P D, \quad (9)$$

$S$  being the assumed strain  $T$  on the driving side, and  $t$ , calculated by equation (6), on the slack side.

It is to be regretted that accurate data are not available to determine the constants needed in the equations for wear and for friction on the pulley.

Table 36.—TRANSMITTING POWER: *Comparison of Ropes.*

Locked Wire Rope made of Patent Crucible Steel.		Ordinary Round Wire Rope made of Patent Crucible Steel.			Tarred Hemp Rope.		Working Load for Inclines $\frac{3}{4}$ th of Breaking Strain.	Working Load for Shafts $\frac{1}{4}$ th of Breaking Strain.	Breaking Strain.
Circumference in inches.	Weight per fathom.	Circumference in inches.	Weight per fathom, rope made entirely of wire.	Weight per fathom, rope made with hemp centre core.	Circumference in inches.	Weight per fathom.			
5	lb. 34	6 $\frac{1}{2}$	lb. 44	lb. 38	22	121	ton. cwt. 19 13	ton. cwt. 14 15	ton. 118
4 $\frac{1}{2}$	31	6 $\frac{1}{4}$	40	35	21	110	18 6	13 15	110
4 $\frac{1}{4}$	28	6	37	32	20	100	16 13	12 10	100
4 $\frac{1}{8}$	25	5 $\frac{1}{2}$	30	26	19	91	14 3	10 12	85
4	22	5	25 $\frac{1}{2}$	23	18	81	12 10	9 7	75
3 $\frac{7}{8}$	20	4 $\frac{3}{4}$	24	22	17	72	10 16	8 2	65
3 $\frac{1}{2}$	17 $\frac{1}{2}$	4 $\frac{1}{2}$	22	20	15	56	10 0	7 10	60
3 $\frac{1}{4}$	15 $\frac{1}{2}$	4	18 $\frac{1}{2}$	16 $\frac{1}{2}$	14	48	8 6	6 5	50
3	13 $\frac{1}{2}$	3 $\frac{7}{8}$	18 $\frac{1}{4}$	15 $\frac{1}{4}$	13	42	6 16	5 2	41
2 $\frac{3}{4}$	11	3 $\frac{1}{2}$	17	14 $\frac{1}{4}$	12	36	6 6	4 15	38
2 $\frac{1}{2}$	8 $\frac{1}{2}$	3 $\frac{1}{4}$	10 $\frac{3}{4}$	9 $\frac{1}{2}$	11	31	5 0	3 15	30
2 $\frac{1}{4}$	7	3	9 $\frac{1}{2}$	8	10	25	4 3	3 2	25
2	5 $\frac{1}{2}$	2 $\frac{5}{8}$	7	6 $\frac{1}{2}$	9	20	3 3	2 7	19

Table 37.—TRANSMITTING POWER: *Comparative Efficiency of Systems.* (Beringer.)

Distance of Transmission.	Electric.	Hydraulic.	Pneumatic.	Wire Rope.
300 ft.	•69	•50	•55	•96
1,500 „	•68	•50	•55	•93
3,000 „	•66	•50	•55	•90
15,000 „	•60	•40	•50	•60
30,000 „	•51	•35	•50	•36
60,000 „	•32	•20	•40	•13

It appears from this table that wire rope is most efficient up to about 3 miles, beyond which electric and pneumatic transmission are most efficient.



**Table 38.—TRANSMITTING POWER: Comparative Cost of Plants per H.P. transmitted. (Beringer.)**

Maximum H.P. transmitted.	Distance of transmission.	Capital outlay per H.P.			
		Electric.	Hydraulic.	Pneumatic.	Wire Rope.
5	ft.	£	£	£	£
	300	73	40	71	6
	1,500	76	64	94	30
	3,000	79	94	204	59
	15,000	105	348	584	296
	30,000	138	594	1,060	740
	60,000	204	1,206	2,000	1,188
10	300	50	29	58	5
	1,500	53	44	70	22
	3,000	55	63	86	46
	15,000	75	214	208	225
	30,000	100	406	360	448
	60,000	150	784	662	910
50	300	39	16	30	2
	1,500	40	20	35	7
	3,000	41	30	41	14
	15,000	54	89	86	67
	30,000	67	166	143	132
	60,000	97	316	258	265
100	300	31	14	25	1
	1,500	32	20	29	4
	3,000	34	27	33	8
	15,000	44	86	65	40
	30,000	57	160	106	79
	60,000	85	302	187	158

**Table 39.—TRANSMITTING POWER: Comparative Cost per Steam Power H.P. received. (Beringer.)**

Maximum H.P. transmitted.	Distance of transmission.	Cost per H.P. received.			
		Electric.	Hydraulic.	Pneumatic.	Wire Rope.
5	ft.	d.	d.	d.	d.
	300	2·3	2·55	2·75	1·15
	1,500	2·35	2·9	3·0	1·45
	3,000	2·45	3·2	3·35	2·9
	15,000	2·9	6·6	5·3	5·6
	30,000	3·35	10·65	9·65	10·5
	60,000	5·25	19·25	16·95	23·0
10	300	2·0	2·4	2·55	1·15
	1,500	2·1	2·6	2·7	1·4
	3,000	2·15	2·85	2·9	1·75
	15,000	2·55	5·65	4·55	4·55
	30,000	3·65	7·8	6·35	8·6
	60,000	4·9	14·5	10·55	19·35

Table 39.—TRANSMITTING POWER, &c.—*continued.*

Maximum H.P. transmitted.	Distance of transmission.	Cost per H.P. received.			
		Electric.	Hydraulic.	Pneumatic.	Wire Rope.
50	ft.	<i>d.</i>	<i>d.</i>	<i>d.</i>	<i>d.</i>
	300	1·9	1·65	2·05	1·1
	1,500	1·95	1·7	2·15	1·2
	3,000	2·0	1·8	2·2	1·3
	15,000	2·3	2·95	2·9	2·55
	30,000	2·8	4·25	3·6	4·55
	60,000	4·3	7·9	5·35	11·25
100	300	1·8	1·65	2·0	1·1
	1,500	1·85	1·7	2·05	1·15
	3,000	1·95	1·8	2·1	1·25
	15,000	2·2	2·9	2·65	2·25
	30,000	2·65	4·2	3·15	3·9
	60,000	4·15	6·95	4·55	9·85

Table 40.—TRANSMITTING POWER: *Comparative Cost per Water Power H.P. received.* (Beringer.)

Maximum H.P. transmitted.	Distance transmitted.	Cost per H.P. received.			
		Electric.	Hydraulic.	Pneumatic.	Wire Rope
5	ft.	<i>d.</i>	<i>d.</i>	<i>d.</i>	<i>d.</i>
	300	·35	·29	·40	·11
	1,500	·36	·38	·47	·19
	3,000	·37	·48	·58	·30
	15,000	·45	1·40	1·28	1·26
	30,000	·52	2·53	2·43	2·53
	60,000	·85	4·85	4·50	4·92
10	300	·27	·25	·35	·09
	1,500	·28	·30	·38	·17
	3,000	·29	·37	·45	·25
	15,000	·36	·96	·89	·97
	30,000	·47	1·56	1·44	1·93
	60,000	·72	3·21	4·02	4·05
50	300	·23	·15	·22	·09
	1,500	·24	·18	·24	·11
	3,000	·26	·22	·28	·13
	15,000	·29	·46	·44	·38
	30,000	·31	·77	·65	·73
	60,000	·55	1·44	1·09	1·63
100	300	·20	·16	·22	·08
	1,500	·22	·17	·23	·10
	3,000	·23	·19	·24	·11
	15,000	·26	·43	·36	·28
	30,000	·32	·73	·48	·48
	60,000	·50	1·15	·84	1·20

Table 41.—TRANSMITTING POWER: *Hydraulic.*

*Formulæ for the flow of water, in which v is the velocity in inches per second and s the hydraulic inclination. (Kutter.)*

For smooth pipes $\frac{1}{2}$ in. to $2\frac{1}{2}$ in. diameter..	..	$v = 107 d^{.9} \sqrt{s}$
„ „ $2\frac{1}{2}$ „ 5 „	.. ..	$v = 115 d^{.8} \sqrt{s}$
„ „ 5 „ 10 „	.. ..	$v = 134 d^{.7} \sqrt{s}$
„ „ 10 „ 72 „	.. ..	$v = 166 d^{.6} \sqrt{s}$
„ „ 6 ft. to 400 ft. „	.. ..	$v = 256 \sqrt{d s}$
For moderately smooth pipes $\frac{1}{2}$ in. to $2\frac{1}{2}$ in. dia.		$v = 63 d \sqrt{s}$
„ „ $2\frac{1}{2}$ „ 5 „		$v = 68 d^{.9} \sqrt{s}$
„ „ 5 „ 10 „		$v = 78 d^{.8} \sqrt{s}$
„ „ 10 „ 24 „		$v = 100 d^{.7} \sqrt{s}$
„ „ 24 „ 96 „		$v = 138 d^{.6} \sqrt{s}$
„ „ 8 ft. to 400 ft. „		$v = 221 \sqrt{d s}$

Table 42.—TRANSMITTING POWER: *Electric Mining Motors.*

H.P. of Motor.	Speed.	Volts.	Amperes.	Approximate Weight.	Price of Motor.	Size of Lead-covered and Double Insulation Cable recommended.	Approximate Cost of Cable per Mile.	Price of Dynamo.
2	1200	200	9.5	3 cwt.	£ 30	B.W.G. $\frac{7}{16}$	£ 60	£ 34
4	1200	200	18.5	4½ „	40	$\frac{7}{16}$ $\frac{7}{16}$	80	45
6	1200	200	27.5	6 „	50	$\frac{7}{16}$ $\frac{1}{2}$	100	57
9	1000	250	31.5	10 „	75	$\frac{1}{2}$ $\frac{1}{2}$	120	84
12	850	300	35.0	15 „	100	$\frac{1}{2}$ $\frac{1}{2}$	120	112
16	800	350	39.0	1 ton	125	$\frac{1}{2}$ $\frac{1}{2}$	150	142
20	750	400	41.5	1½ „	150	$\frac{1}{2}$ $\frac{1}{2}$	150	170
25	700	450	46.5	2 tons	175	$\frac{1}{2}$ $\frac{1}{2}$	175	200
30	650	500	49.5	2½ „	200	$\frac{1}{2}$ $\frac{1}{2}$	175	225

Table 43.—Transmission of Stored Power. (Kapp.)

Source of Power.	Distance in Miles Attainable with 90 per cent. Efficiency of Transmission over—		
	Road.	Train.	Rail.
Coal and steam engine.. ..	115	270	1,300
Corn and horse .. ..	52	170	440
Storage battery and electromotor	4	10	26

Table 44.—*Transmission Plant for 5 H.P. (Kapp.)*

Distance of Transmission in miles.	Annual Cost per H.P. delivered, if the Transmission is—		
	By Batteries.	Direct.	
		Overhead.	Underground.
	£	£	£
1	36·1	22·8	33·6
2	37·6	25·6	47·2
3	39·1	28·0	60·0
4	40·6	30·6	74·0
5	42·1	33·0	87·0

Table 45.—*Formulae for Electric Transmission of Power. (Kapp.)*

$$\begin{aligned} \text{Volts} &= H v l 10^{-8} \\ \text{Kilogrammes} &= H c l \\ &\underline{\hspace{1.5cm}} \\ &9,810,000 \end{aligned}$$

C Total current through armature.

c Current through single armature conductor.

$e_a$  E.M.F. in armature in volts.

$\tau$  Number of active conductors counted all round armature.

$p$  Number of pairs of poles ( $p = 1$  in a two-pole machine).

$n$  Speed in revolutions per minute.

F Total induction in C.G.S. lines.

Z „ „ English lines.

$$\text{Electromotive force} \left\{ \begin{array}{l} e_a = F \tau \frac{n}{60} 10^{-8} \\ e_a = Z \tau n 10^{-6} \end{array} \right\} \text{for two pole machines.}$$

$$\left\{ \begin{array}{l} e_a = p F \tau \frac{n}{60} 10^{-8} \\ e_a = p Z \tau n 10^{-6} \end{array} \right\} \text{for multipolar machines with series wound armature.}$$

$$\text{Torque} \left\{ \begin{array}{l} \text{Kilogramme-metres} = 1 \cdot 615 F \tau C 10^{-10} \\ \text{Foot-pounds} = 7 \cdot 05 Z \tau C 10^{-6} \end{array} \right\} \text{for two-pole machines.}$$

$$\left\{ \begin{array}{l} \text{Kilogramme-metres} = 3 \cdot 23 F \tau c p 10^{-10} \\ \text{Foot-pounds} = 14 \cdot 10 Z \tau c p 10^{-6} \end{array} \right\} \text{for multipolar machines.}$$

Table 46.—*Most Economical Current for Electric Power Transmission.*  
(Kapp.)

D	..	..	Distance in miles.
a	..	..	Section of conductor in sq. in.
E	..	..	Terminal volts at generator.
e	..	..	Terminal volts at motor.
HP <sub>g</sub>	..	..	Brake horse-power required to drive generator.
HP <sub>m</sub>	..	..	Brake horse-power obtained from motor.
c	..	..	Current in amperes.
			Efficiency of generator, 90 per cent.; efficiency of motor, 90 per cent.
g	..	..	Cost in £ per electrical horse-power output of generator.
m	..	..	Cost in £ per brake horse-power output of motor, including regulating gear.
G = .9g HP <sub>g</sub>	..	..	Cost in £ of generator.
M = m HP <sub>m</sub>	..	..	Cost in £ of motor and regulating gear.
t = 18.2 Da	..	..	Weight in tons of copper in line.
K	..	..	Cost in £ per ton of copper, including labour in erection.
s	..	..	Cost in £ of supports of line per mile run.
p	..	..	Cost in £ of one annual brake horse-power absorbed by generator.
q	..	..	Percentage for interest and depreciation on the whole plant.

$$\text{Capital outlay} = g \frac{Ec}{746} + m \text{HP}_m + Ds + \frac{1.6 K D^2 c^2}{Ec - 830 \text{HP}_m} = A.$$

$$\text{Annual cost per brake horse-power delivered} = q \frac{A}{\text{HP}_m} + p \frac{\text{HP}_g}{\text{HP}_m}.$$

$$\text{Put } B = \frac{Ep}{670} + q \frac{Eq}{746}.$$

$$j = \frac{830}{E} \text{HP}_m, \text{ the current which would be required if the line had no resistance,}$$

and  $\beta = j^2 \frac{EB}{1.6 q K D^2 + EB}$ ; then the most economical current at the given voltage E is—

$$c = j \left\{ 1 + \sqrt{1 - \frac{\beta}{j^2}} \right\}$$

$$c = j \left\{ 1 + \sqrt{\frac{1.6 q K D^2}{1.6 q K D^2 + BE}} \right\}$$

For very long distances the term under the square root approaches unity, and the most economical current the value  $2j$ ; from which it follows that under no circumstances will it be economical to lose more than half the total power in the line.

Table 47.—*Cost of Transmission of Power Plant.* (Kapp.)

Distance in Miles.	H.P. Delivered.	Speed of Machines.	Cost in £.			Total Cost.*	Cost per H.P.
			Gen.	Mot.	Line.		
						£	£
1·870	85	450	640	560	440	1,880	22·2
·280	195	500	760	680	132	1,800	9·7
·280	51	600	320	280	60	720	14·1
·375	90	550	520	480	80	1,240	13·8
·560	71	600	440	400	60	1,040	14·6
·280	40	700	260	240	20	640	16
·375	75	600	480	440	68	1,120	15
·500	87	500	520	480	100	1,260	14·5
1·560	150	600	760	720	330	2,050	13·7
·220	93	450	440	420	232	1,270	13·7
6·250	11	900	132	110	480	960	87
2·200	51	600	360	320	300	1,140	22·4
·187	60	900	240	220	18	600	10
5·000	41	750	240	200	344	1,020	24·8
3·750	220	600	1,040	960	640	2,960	13·5
·002	15	600	112	104	8	252	16·8
·250	19	700	160	160	20	390	20·5

\* This includes regulating apparatus, instruments, posts, insulators, lightning arresters, erection, and supervision.

Table 48.—*Schaffhausen Electric Power Transmission Plant.* (Kapp.)

	Generators.	Twin Motor.	Small Motors.
Number of machines .. .. .	2	1	2
Normal horse-power .. .. .	300	380	60
Number of poles in magnet fields .. .. .	6	6	2
Revolutions per minute .. .. .	300	300	350
Terminal voltage .. .. .	624	600	600
Normal current, amperes .. .. .	330	500	81
Diameter of armature, inches .. .. .	47½	42½	23½
Length of armature core, inches .. .. .	20	20½	22½
Radial depth of armature core .. .. .	8	7	4½
Section of armature conductor, square inches	·103	·078	·0287
Number of armature conductors .. .. .	316	316	540
Number of commutator segments .. .. .	158	158	90
Loss in armature resistance per cent. .. .. .	1·46	1·52	2·7
Induction in armature, C.G.S. measure .. .. .	7,500	7,600	15,800
Shunt resistance, ohms .. .. .	140	143	295
Loss in shunt excitation per cent. .. .. .	1·35	1·68	—
Main turns per magnet .. .. .	6	4	—
Loss in main excitation per cent. .. .. .	·3	·2	—
Type of armature .. .. .	Drum	Drum	Cylinder

The power is transmitted from a turbine station across the Rhine to the Schaffhausen spinning mills, a distance of about 750 yd. At

*Schaffhausen Plant—continued.*

the generating station are four turbines, each of 350 H.P., of which only two are at present in use, and the energy delivered at the turbine pulleys is sold to the mill owners at the rate of 2l. 16s. per H.P. per annum. From the turbine pulleys two 6-pole dynamos are driven by cotton ropes, each dynamo having an output of 330 amperes at 624 volts when running at 300 rev. per minute. These machines are over-compounded, so as to give a constant potential of 600 volts at the motor end of the line, and in ordinary working are coupled in parallel. At the receiving station is a twin motor of 380 H.P., and two other motors, each of 60 H.P. The twin motor is 6-pole, and the smaller motors 2-pole, and the power is transmitted from them to the mill shafting by cotton ropes. There are four main conductors, all overhead, each having a sectional area of .437 sq. in., and being supported by iron towers 46 ft. high; the span across the river is 330 ft., and each of the remaining spans is 430 ft. The guaranteed commercial efficiency reckoned from the turbine pulleys is 78 per cent., the variation of speed of the motors between full and no load not more than 3 per cent., the life of a set of brushes not less than 2000 hours, and of a commutator not less than 20,000 hours. The total cost of the electrical part of the plant, including iron towers and erection, was 6800l.

The use of alternate current generators and motors for large transmissions has much in its favour; there are no commutators, and by having transformers at both ends of the line the working potential may be 10,000 or 25,000 volts, or even higher still, while the potential at the machines is only a few hundred volts. An ordinary alternate-current dynamo can easily be run as a motor, but, as such, it is not self-starting, and if overloaded to the extent of 50–100 per cent., may get out of step with the supply current and come to a standstill. There is another method of alternate-current transmission, known as the “three-phase current” system, which has neither of the above objections; it is a development of the Ferraris two-wire and of the Tesla three-wire systems, but with it the transmission and plant efficiencies are much greater than with the Tesla system. An objection to the Ferraris system is that the speed of the motor is not self-regulating, but may vary from zero to the synchronising speed according to the load.

**TRANSMITTING POWER:** *Electric Accumulators in Mines.* (Pocock.)

The use of accumulators in mines is not far off, and it will be of interest to many to see how far this reservoir of power will bear filling and drawing upon at the present time, and what the relative cost of the two electrical systems may be expected to be, not so much in first outlay as in the running expenses of the plant.

The first thing to be decided is the weight of these accumulators, and the easiest way to define this, is the weight per H.P. Salom says it takes 25 lb. of battery to give 1 H.P.-hour, and that to give 100 H.P.-hours, or 10 H.P. for 10 hours, requires 5500 lb. of battery

*Electric Accumulators—continued.*

or 220 elements; but 25 lb. is the net weight and 32 lb. the real total upon which we must base our calculations, so that we have a total of 7040 lb. as the weight of this battery. Then as to the room this will take upon a mine-locomotive. A mine-locomotive of 10 H.P. should not be more than 9 ft. long, and 2 ft. of this will be taken up by the bumpers, leaving 7 ft. in length for the battery. Then for a 3 ft. track it should not be more than 5 ft. wide. Allowing 1 in. all round a cell, it will be possible to set 96 of these on the floor-space of the locomotive; but we must have 14 more than this, which will make the width 68 in. The height of this cell is 8 in.; and, allowing 2 in. space above it, and  $1\frac{1}{2}$  in. of plank, the top of the second tier will be  $19\frac{1}{2}$  in. high above the floor.

If the motor is to be placed below this floor (and there is no other place for it), then the bottom of the floor will be 2·6 in. from the track; and, allowing the floor to be 3 in. thick to stand the weight, the top of this car will be 4 ft.  $4\frac{1}{2}$  in. above the track. Remembering that the height of the 40 H.P. motor at Lykens Valley is only 4 ft., and that the one at Erie Colliery, also 40 H.P., is 4 ft. 4 in. high, and that they are both narrower and of the same length as the proposed storage-motor, and of four times the power, there is certainly one point established against the present use of accumulators.

Table 49.—*Weight, etc., of Electric Mine-Locomotives.* (Pocock.)

Location.	Horse-power of Motor.	Weight of Locomotive. lb.	Largest Load. Tons.	Speed. Miles per hour.
Zankerode ..	4·5 ..	3000 ..	$13\frac{1}{2}$	6
Paulus ..	5 to 6 ..	4200 ..	..	6
Lykens ..	40 ..	12,000 ..	165	6·8
" ..	40 ..	12,000 ..	150	6·8
Shawnee ..	.. ..	4500 ..	21	5
Buckingham ..	.. ..	7000 ..	60	8
" ..	.. ..	4000 ..	30	8
Bear Run ..	60 ..	18,000 ..	150	6
Erie ..	40 ..	13,500 ..	107	6

To the weight of accumulators, 7040 lb., must be added that of motor, say 1300 lb., wheels and axles, say 1100 lb., and frame of machine, say, for strength alone, 1400 lb., giving a total weight of 10,840 lb.

From this it appears that the small German motors weigh about 700 lb. per H.P., and that the large American motors only weigh 300 lb. per H.P., whereas the accumulator-motor would weigh at least 1000 lb. per H.P. It is true that weight is necessary to traction, but it is also true that unnecessary weight will entail loss of power, and it appears that 700 lb. per H.P. is found to work satisfactorily with small motors, and that the weight per H.P.



*Electric Mine Locomotives—continued.*

decreases as the H.P. increases. Consequently, for a 10 H.P. motor, 1000 lb. per H.P. appears to be too high. There will be a waste of power in moving this weight, and, if we wished to operate a 40 H.P. locomotive with batteries, the number of cells would be 880, and their weight 28,160 lb. They might be divided into two batteries and towed in a tender, but even then each would weigh 14,080 lb., and this would absorb at least 500 lb. of the total pull of the motor, when running on the level, and considerably more where grades are to be overcome.

Dr. Lewis Bell has pointed out that, while a good roadbed is necessary for electrical traction by overhead wire, it is even more imperatively so when storage-batteries are used. We have found in practice that a 25 lb.-per-yard steel rail is too light for a locomotive of 13,000 lb. weight to be run upon; therefore, there is no saving to be looked for in this direction by the use of accumulators. On the contrary, when we begin to put in a roadbed heavy enough to stand the weight of a locomotive weighing, say, 23,000 lb., there are many disadvantages that the colliery-manager will be the first to see. Besides the first cost of the track, the keeping of this weight of track in good repair in a mine where the floor is for ever moving (as it is in many of our mines), would be a work of no slight expense in itself. It appears, therefore, that not much is to be expected from accumulators as a means of haulage.

However, this is one side of the question only. There is another side which should be considered, and that is the use of the accumulator-motor in collecting the cars to a point where the heavy haulage-motor can reach them. The prospect, as viewed from this point, is more encouraging. From what I have seen of the work, a motor of about 5 H.P. would do the work of 3-4 mules, and the weight would be about 5000 lb., as follows:

									lb.
Accumulators (110 cells)	..	..	..	..	..	..	..	..	3500
Motor	..	..	..	..	..	..	..	..	600
Wheels and frame	..	..	..	..	..	..	..	..	1000
									<hr/>
Total weight	..	..	..	..	..	..	..	..	5100

This machine could be built low, so as to take up little height. It is only possible to make this form a commercial success, in my opinion, when the gangways are low and the roofs would have to be cut to gain height enough for mules to work. Then, the cost of the cutting saved by the use of the motor would counterbalance the repairs on the battery, and the extra care and expense in laying and keeping the track in order. The cost of the system may be estimated as follows—assuming the first cost of the locomotive complete to be 4600., and allowing that the mine can afford to charge these cells for 8% per H.P. per year, the generator and engine being already installed and doing work during the day-time,

*Electric Mine Locomotives—continued.*

and this sum representing fuel and interest on machinery. The attendance should not be more than 60*l.* per year, as the pump-man and night engineer can do the work :

Table 50.—*Estimate of Expense of 5 H.P. Accumulator-Motor.*

	£	s.
Interest, at 6 per cent., on 460 <i>l.</i> .. .. .	27	12
Repairs to battery .. .. .	100	0
Repairs to motor, etc. .. .. .	30	0
Cost of power, at 8 <i>l.</i> per H.P. .. .. .	40	0
Attendance in charging at night .. .. .	60	0
Engineer, at 8 <i>s.</i> per day, for 260 days.. .. .	104	0
	<hr/>	<hr/>
	361	12

Table 51.—*Cost of running three mules and drivers.*

Interest and depreciation (26 per cent.) on 90 <i>l.</i> ..	23	10
Feed, shoeing, harness, and attention, at 1 <i>s.</i> 4 <i>d.</i> per day .. .. .	72	5
Three drivers, for 260 days, at 8 <i>s.</i> per day ..	312	0
Total .. .. .	407	15
Less .. .. .	361	12
Annual saving on 3 mules ..	46	3
Or, for 4 mules : total expense .. .. .	543	10
Less .. .. .	361	12
Annual saving on 4 mules ..	181	18

Or, about 44 per cent. on the investment, under the circumstances assumed.

The rail and track being an important item in the economy of this method, I think that perhaps the cheapest, and at the same time the best method would be to use 20–25 lb. steel rail, and, in laying the track, to place the ties first about 3 ft. apart centre to centre, and on these, and under each rail, to place a string-piece of wood 1½ by 3 in., nailed to the ties, and spike the rails on the top, keeping the stringer-joints and the rail-joints from coinciding. The combination makes a solid track, and a very smooth-running one, and it has the advantage of not lifting easily into very uneven points; the ends of the rails do not jump as when only laid on the ties, and the track has not the spring to it which is so injurious.

The true place for accumulators at present is in lighting, and it looks as if they could be used to advantage in this connection.

*Electric Accumulators—continued.*

They are very heavy, it is true; but the lighting-arrangement for 8 hours' work would not be a large or very heavy affair, and could be taken to the working-place on the first car, and brought out on the last, so that it would not have to be carried by hand at all. The advantage to the operator would be material, as the men can work better in good light than in poor, and the coal would come faster and cleaner from a well-lighted place. The lighting of switches, turnouts, etc., could be easily accomplished in all parts of the mine, and the jar which would be detrimental to traction would not occur in this case. The charging could be done at night, and a clear steady light delivered during the working hours.

Table 52.—*Transmitting Capacity of Shafting.* (Webber.)

The following table gives the number of horse-power which may be safely transmitted by wrought-iron shafting, properly supported, at 100 rev. per minute:

First Movers, Carrying Main Pulley or Gear.		Second Movers, or Line Shafting, 8 ft. Spans.		Third Movers, or Short Counter Shafts, with Bearings near Pulleys.	
Diameter. in.	H.P.	Diameter. in.	H.P.	Diameter. in.	H.P.
1	1	1	2	1 $\frac{1}{16}$	3
1·25	1·95	1 $\frac{1}{8}$	2·85	1 $\frac{1}{8}$	3·59
1·50	3·37	1 $\frac{1}{4}$	3·90	1 $\frac{1}{4}$	4·27
1·75	5·36	1 $\frac{3}{8}$	5·19	1 $\frac{3}{8}$	5·02
2	8	1 $\frac{1}{2}$	6·74	1 $\frac{1}{2}$	5·85
2·25	11·39	1 $\frac{3}{4}$	8·58	1 $\frac{3}{4}$	6·78
2·50	15·62	1 $\frac{7}{8}$	10·72	1 $\frac{7}{8}$	7·79
2·75	20·80	1 $\frac{15}{16}$	13·18	1 $\frac{7}{8}$	8·91
3	27	2	16	1 $\frac{1}{2}$	10·12
3·25	34·33	2 $\frac{1}{8}$	19·19	1 $\frac{5}{8}$	11·19
3·50	42·87	2 $\frac{1}{4}$	22·78	1 $\frac{1}{2}$	12·87
3·75	52·73	2 $\frac{3}{8}$	26·79	1 $\frac{3}{4}$	14·41
4	64	2 $\frac{1}{2}$	31·24	1 $\frac{1}{2}$	16·07
4·25	76·77	2 $\frac{5}{8}$	36·17	1 $\frac{3}{8}$	17·86
4·50	91·12	2 $\frac{7}{8}$	41·60	1 $\frac{1}{4}$	19·77
4·75	107·17	2 $\frac{15}{16}$	47·53	1 $\frac{1}{2}$	21·81
5	125	3	54	2	24·00
5·25	144·70	3 $\frac{1}{8}$	60·92	2 $\frac{1}{16}$	26·32
5·50	166·37	3 $\frac{1}{4}$	68·66	2 $\frac{1}{8}$	28·78
5·75	190·11	3 $\frac{3}{8}$	76·89	2 $\frac{3}{16}$	31·40
6	216	3 $\frac{1}{2}$	85·74	2 $\frac{1}{4}$	34·17
—	—	3 $\frac{5}{8}$	95·27	2 $\frac{5}{16}$	37·09
—	—	3 $\frac{7}{8}$	105·46	2 $\frac{3}{8}$	40·18
—	—	3 $\frac{15}{16}$	116·37	2 $\frac{7}{16}$	43·44
—	—	4	128	2 $\frac{1}{2}$	46·87

For other velocities, multiply by the number of revolutions and divide by 100.

TRANSMITTING POWER: *Belt Gearing.*

The resistance of belts to slipping is independent of their breadth, consequently there is no advantage derived from increasing their dimension beyond that which is necessary to enable the belt to resist the strain. The ratio of friction to pressure for belts over wooden drums is, for leather belts, when worn  $\cdot 47$ , when new  $\cdot 5$ , and when over turned cast iron pulleys,  $\cdot 24$  and  $\cdot 47$ . A leather belt will safely and continuously resist a strain of 350 lb. per sq. in. of section, and a section of  $\cdot 2$  sq. in. will transmit the equivalent of 1 H.P. at a velocity of 1000 ft. per minute over a wooden drum, and  $\cdot 4$  sq. in. over a turned cast iron pulley. In high speed belting the tension or the breadth of the belt should be increased in order to prevent belt from slipping. Long belts are more effective than short ones. A single belt 1 in. wide, travelling at a velocity of 1000 ft. per minute, transmits 1 H.P. A double belt 1 in. wide, travelling 700 ft. per minute, transmits 1 H.P. When a double belt is long and runs over large pulleys it may be calculated to do 1 H.P. of work at a speed of 500 ft. per minute. The upper side of the pulley should always carry the slack belt. To throw a belt on to its pulleys, when it has been laid off, it should always be laid on to the pulley that is not in motion first, and then be thrown over the edge of the moving pulley on to its face. A belt will transmit about 30 per cent. more power, with a given tension, when the grain (smooth side of the leather) is in contact with the pulley than when the flesh side is turned inward. The leather is also less liable to crack, as the structure on the flesh side is less dense, and the fibres more extensible. The adhesion of belts is greater on polished than on rough pulleys, and is about 50 per cent. greater on a leather covered pulley than on a polished iron pulley. Larger pulleys and drums may be covered with narrow strips of leather or with longer strips wound spirally. Pulley covers are manufactured in strips of the desired width, and reduced to uniform thickness by machinery. Belts should be kept soft and pliable by applying tallow occasionally, and neats-foot or liver oil, with a little rosin when they become hard and dried. Rubber belts ought always to be kept free from grease and animal oils. If they slip, moisten the inside of the belt with boiled linseed oil. Fine chalk sprinkled on over the oil will help the belt.

*To Find Length of Belts.*—*Rule:* Add the diameter of the two pulleys together, multiply by  $3\frac{1}{2}$ , divide the product by two, add to the quotient twice the distance between the centre of the shafts, and the product will be the required length.

*To Calculate Power of Belting.*—1 in. single belt moving at a velocity of 1000 ft. per minute = 1 H.P.; 1 in. double belt moving 700 ft. per minute = 1 H.P. Then H.P. of any belt equals its velocity in ft. per minute, multiplied by its width and divided by 1000 for single and by 700 for double belts.

*Belt Gearing—continued.**To Calculate Speed of Drums and Pulleys.—*

(a) The diameter of the driven being given, to find its number of revolutions. *Rule:* Multiply the diameter of the driver by the number of its revolutions, and divide the product by the diameter of the driven, the quotient will be the number of revolutions of the driven.

(b) The diameter and revolutions of driver being given, to find the diameter of the driven that shall make any given number of revolutions in the same time. *Rule:* Multiply the diameter of the driver by its number of revolutions and divide the product by the number of revolutions of the driven; the quotient will be the diameter.

(c) To ascertain the size of the driver. *Rule:* Multiply the diameter of the driven by the number of revolutions you wish to make, and divide the product by the revolutions of the driver; the quotient will be the diameter of the driver.

In ordering pulleys, the *exact* size of the shaft on which they are to go must be given; and the finish on the face should be flat for shifting belt, rounding for non-shifting belt.

Table 53.—Diameter and Horse-power of Shafting. Revolutions per minute.

Diam. of Shaft.	1	50	75	100	110	120	130	150	175	200	225	250	300	400	500	1000
in.	H.P.	H.P.	H.P.	H.P.	H.P.	H.P.	H.P.	H.P.	H.P.	H.P.	H.P.	H.P.	H.P.	H.P.	H.P.	H.P.
1	.0099	.495	.742	.980	1.039	1.118	1.287	1.485	1.732	1.980	2.229	2.475	2.97	3.960	4.990	9.9
1 1/4	.0175	.875	1.3125	1.75	1.925	2.10	2.275	2.635	3.162	3.5	3.937	4.375	5.25	7.0	8.75	17.5
1 1/2	.03	1.50	2.25	3.0	3.30	3.60	3.90	4.50	5.25	6.0	6.75	7.50	9.0	12.0	15.0	30.0
1 3/4	.045	2.25	3.375	4.5	4.95	5.4	5.85	6.75	7.875	9.0	10.125	11.25	13.5	18.0	22.5	45.0
2	.07	3.5	5.15	7.0	7.7	8.4	9.1	10.5	12.5	14.0	15.75	17.5	21.0	28.0	35.0	70.0
2 1/4	.1	5.0	7.5	10.0	11.0	12.0	13.0	15.0	17.5	20.0	22.5	25.0	30.0	40.0	50.0	100.0
2 1/2	.130	6.5	9.75	13.0	14.3	15.6	16.9	19.5	22.75	26.0	29.25	32.5	39.0	52.0	65.0	130.0
2 3/4	.165	7.5	11.25	15.0	16.5	18.0	19.5	22.5	26.25	30.0	33.75	37.5	45.0	60.0	75.0	150.0
3	.225	11.25	16.875	22.5	24.75	27.0	29.25	33.75	39.375	45.0	50.6	56.2	67.5	90.0	112.5	225.0
3 1/4	.275	13.75	21.62	27.5	30.25	32.0	34.75	41.25	47.75	55.0	61.875	68.75	82.5	110.0	137.5	275.0
3 1/2	.33	16.5	24.75	33.0	36.3	40.20	42.9	49.5	57.75	66.0	74.25	82.5	99.0	132.0	165.0	330.0
3 3/4	.412	20.6	30.9	41.2	45.32	49.44	53.56	61.8	71.10	82.4	92.7	103.0	123.6	164.3	206.0	412.0
4	.5	25.0	37.5	50.0	55.0	60.0	65.0	75.0	87.5	100.0	112.5	125.0	150.0	200.0	250.0	500.0
4 1/4	.6	30.0	45.6	60.0	66.0	72.0	78.0	90.0	105.0	120.0	135.0	150.0	180.0	240.0	300.0	600.0
4 1/2	.725	35.25	54.27	72.5	79.75	86.0	94.25	108.70	126.87	145.0	163.0	180.0	217.0	280.0	350.0	725.0
4 3/4	.85	42.5	63.75	85.0	93.5	102.0	110.0	127.0	143.0	170.0	191.0	212.0	255.0	340.0	425.0	850.0
5	1.0	50.0	75.0	100.0	110.0	120.0	130.0	150.0	175.0	200.0	225.0	250.0	300.0	400.0	500.0	1000.0
5 1/4	1.325	66.0	99.0	132.0	145.0	159.0	172.0	195.0	232.0	265.0	298.0	331.0	397.0	530.0	662.0	1324.0
5 1/2	1.725	86.0	139.0	172.0	189.0	207.0	221.0	258.0	301.0	345.0	388.0	431.0	517.0	690.0	862.0	1724.0
6	2.175	108.0	163.0	217.0	239.0	261.0	282.0	326.0	380.0	435.0	489.0	543.0	652.0	870.0	1087.0	2174.0
7	2.7	135.0	202.0	270.0	297.0	324.0	351.0	405.0	472.0	540.0	607.0	675.0	810.0	1080.0	1350.0	2700.0

This table is calculated for general shafting, transmitting power by belt pulleys. For shafting carrying heavy weights or transmitting power by gears, diameter should be increased accordingly.



Table 55.—TRANSMITTING POWER: Breadth of Belts in Inches for different Motive Forces and Angles of Contact.  
(Nystrom.)

Motive Force.	Whole Angle of Contact 2 Z.									
	60°	70°	80°	90°	100°	110°	120°	130°	140°	150°
F lb.	B in.	B in.	B in.	B in.	B in.	B in.	B in.	B in.	B in.	B in.
10	0.424	0.372	0.331	0.300	0.275	0.254	0.238	0.223	0.211	0.200
20	0.847	0.743	0.662	0.599	0.546	0.509	0.475	0.446	0.421	0.400
30	1.271	1.115	0.993	0.893	0.824	0.763	0.713	0.670	0.632	0.600
40	1.695	1.487	1.324	1.198	1.099	1.018	0.950	0.893	0.842	0.800
50	2.119	1.859	1.655	1.497	1.374	1.272	1.183	1.116	1.053	1.000
60	2.543	2.230	1.997	1.796	1.648	1.526	1.425	1.339	1.263	1.200
70	2.966	2.602	2.318	2.095	1.923	1.780	1.663	1.562	1.474	1.400
80	3.390	2.974	2.648	2.396	2.193	2.036	1.900	1.786	1.684	1.600
90	3.813	3.345	2.990	2.695	2.472	2.290	2.133	2.009	1.895	1.800
100	4.237	3.717	3.311	2.994	2.747	2.544	2.375	2.233	2.105	2.000
120	5.034	4.460	3.974	3.592	3.296	3.053	2.850	2.678	2.526	2.400
140	5.932	5.204	4.636	4.190	3.846	3.560	3.326	3.124	2.948	2.800
160	6.780	5.948	5.296	4.792	4.396	4.072	3.800	3.572	3.368	3.200
180	7.626	6.690	5.960	5.390	4.944	4.580	4.276	4.018	3.790	3.600
200	8.474	7.434	6.622	5.988	5.494	5.088	4.750	4.464	4.210	4.000
220	9.321	8.177	7.284	6.586	6.043	5.596	5.225	4.910	4.631	4.400
240	10.17	8.920	7.948	7.184	6.592	6.104	5.700	5.356	5.052	4.800
260	11.02	9.663	8.610	7.783	7.141	6.613	6.175	5.800	5.473	5.200
280	11.86	10.41	9.273	8.380	7.692	7.120	6.652	6.248	5.896	5.600
300	12.71	11.15	9.933	8.982	8.241	7.632	7.125	6.696	6.315	6.000
320	13.56	11.90	10.59	9.584	8.692	8.144	7.600	7.144	6.736	6.400
340	14.41	12.64	11.21	10.18	9.241	8.652	8.075	7.590	7.157	6.800
360	15.25	13.38	11.92	10.78	9.948	9.353	8.753	8.236	7.780	7.400
380	16.10	14.12	12.53	11.33	10.53	9.669	9.027	8.482	8.001	7.600
400	16.95	14.87	13.24	11.98	10.99	10.180	9.500	8.928	8.420	8.000



Table 55—continued.

Motive Force.	Whole Angle of Contact 2 Z.									
	60°	70°	80°	90°	100°	110°	120°	130°	140°	150°
F lb.	B in.	B in.	B in.	B in.	B in.	B in.	B in.	B in.	B in.	B in.
420	17.80	15.61	13.90	12.58	11.54	10.69	9.97	9.34	8.84	8.40
440	18.64	16.35	14.57	13.17	12.09	11.19	10.45	9.82	9.26	8.80
460	19.49	17.09	15.23	13.77	12.64	11.70	10.93	10.27	9.68	9.20
480	20.34	17.84	15.90	14.37	13.13	12.21	11.40	10.71	10.10	9.60
500	21.19	18.59	16.55	14.97	13.74	12.72	11.88	11.16	10.53	10.00
600	25.42	22.30	19.87	17.96	16.48	15.26	14.25	13.39	12.63	12.00
700	29.66	26.02	23.18	20.95	19.23	17.80	16.63	15.62	14.74	14.00
800	33.90	29.74	26.48	23.96	21.93	20.36	19.00	17.86	16.84	16.00
900	38.13	33.45	29.80	26.95	24.72	22.90	21.38	20.09	18.95	18.00
1000	42.37	37.17	33.11	29.94	27.47	25.44	23.75	22.32	21.05	20.00
1100	46.61	40.89	36.42	32.93	29.22	27.98	26.12	24.55	23.15	22.00
1200	50.84	44.60	39.74	35.92	32.96	30.52	28.50	26.78	25.26	24.00
1300	55.08	48.32	40.05	38.91	35.71	33.06	30.37	29.01	27.36	26.00
1400	59.32	52.04	46.36	41.90	38.56	35.60	33.26	31.24	29.48	28.00
1500	63.56	55.76	49.67	44.89	41.31	38.14	36.63	33.47	31.58	30.00
1600	67.80	59.48	52.96	47.92	43.96	40.72	38.00	35.72	33.68	32.00
1700	72.04	63.20	56.27	50.91	46.71	43.26	40.38	37.95	35.78	34.00
1800	76.26	66.90	59.60	53.90	49.44	45.80	42.76	40.18	37.90	36.00
1900	80.50	70.62	62.91	56.89	52.19	48.34	45.14	42.41	40.01	38.00
2000	84.74	74.34	66.22	59.88	54.94	50.88	47.50	44.64	42.10	40.00
2100	88.98	78.06	69.53	62.87	57.69	53.42	49.88	46.87	44.21	42.00
2200	93.21	81.77	72.84	65.86	60.43	55.96	52.25	49.10	46.31	44.00
2300	97.45	85.49	76.15	68.85	63.18	58.50	54.63	51.33	48.42	46.00
2400	101.70	89.20	79.48	71.84	65.92	61.04	57.00	53.56	50.52	48.00
2500	105.90	92.95	82.75	74.85	68.70	63.50	59.40	55.80	52.65	50.00

Table 55—continued.

Motive Force.	Whole Angle of Contact 2 Z.									
	160°	170°	180°	190°	200°	210°	220°	230°	240°	250°
F lb.	B in.	B in.	B in.	B in.	B in.	B in.	B in.	B in.	B in.	B in.
10	0.190	0.182	0.175	0.163	0.162	0.157	0.152	0.148	0.144	0.140
20	0.381	0.365	0.350	0.337	0.325	0.314	0.304	0.295	0.287	0.280
30	0.571	0.547	0.525	0.505	0.487	0.472	0.457	0.442	0.431	0.420
40	0.762	0.730	0.700	0.673	0.649	0.629	0.609	0.591	0.574	0.560
50	0.952	0.912	0.875	0.841	0.811	0.786	0.761	0.738	0.718	0.700
60	1.143	1.094	1.051	1.010	0.974	0.943	0.913	0.884	0.862	0.840
70	1.333	1.276	1.226	1.178	1.136	1.100	1.065	1.032	1.005	0.980
80	1.524	1.459	1.401	1.346	1.298	1.258	1.218	1.182	1.149	1.120
90	1.714	1.642	1.576	1.515	1.461	1.415	1.370	1.326	1.292	1.260
100	1.905	1.824	1.751	1.683	1.623	1.572	1.522	1.477	1.436	1.400
120	2.286	2.188	2.102	2.020	1.948	1.886	1.826	1.768	1.723	1.680
140	2.667	2.553	2.452	2.357	2.273	2.200	2.130	2.063	2.010	1.960
160	3.048	2.918	2.802	2.692	2.596	2.516	2.436	2.364	2.294	2.240
180	3.429	3.283	3.152	3.029	2.921	2.830	2.740	2.659	2.586	2.520
200	3.810	3.648	3.502	3.366	3.246	3.144	3.044	2.954	2.872	2.800
220	4.191	4.013	3.852	3.703	3.571	3.458	3.348	3.249	3.159	3.080
240	4.572	4.376	4.204	4.040	3.896	3.772	3.652	3.536	3.446	3.360
260	4.953	4.741	4.554	4.377	4.221	4.086	3.956	3.831	3.733	3.640
280	5.334	5.105	4.904	4.714	4.546	4.400	4.266	4.126	4.020	3.920
300	5.715	5.472	5.253	5.049	4.869	4.716	4.566	4.421	4.308	4.200
320	6.096	5.836	5.604	5.394	5.192	5.032	4.872	4.728	4.596	4.480
340	6.477	6.201	5.954	5.720	5.516	5.346	5.176	5.023	4.883	4.760
360	6.858	6.564	6.306	6.060	5.944	5.658	5.478	5.304	5.169	5.040
380	7.239	6.929	6.656	6.397	6.269	5.972	5.782	5.599	5.456	5.320
400	7.620	7.296	7.004	6.732	6.732	6.333	6.038	5.908	5.744	5.600

Table 55—continued.

Motive Force.	Whole Angle of Contact 2 Z.									
	160°	170°	180°	190°	200°	210°	220°	230°	240°	250°
F lb.	B in.	B in.	B in.	B in.	B in.	B in.	B in.	B in.	B in.	B in.
420	8.001	7.661	7.354	7.068	6.816	6.602	6.492	6.203	6.031	5.88
440	8.382	8.026	7.704	7.406	7.142	6.916	6.696	6.498	6.318	6.16
460	8.763	8.391	8.054	7.743	7.466	7.230	7.000	6.793	6.605	6.44
480	9.144	8.752	8.408	8.080	7.792	7.544	7.304	7.072	6.892	6.72
500	9.525	9.120	8.755	8.415	8.115	7.860	7.610	7.385	7.180	7.00
600	11.43	10.94	10.51	10.10	9.738	9.432	9.132	8.842	8.616	8.40
700	13.33	12.76	12.26	11.78	11.36	11.00	10.65	10.32	10.04	9.80
800	15.24	14.59	14.01	13.46	12.98	12.54	12.13	11.82	11.49	11.20
900	17.14	16.42	15.76	15.15	14.61	14.15	13.70	13.26	12.92	12.60
1000	19.05	18.24	17.51	16.83	16.23	15.72	15.22	14.77	14.36	14.00
1100	20.95	20.06	19.26	18.51	17.85	17.29	16.74	16.25	15.80	15.40
1200	22.86	21.88	21.02	20.20	19.43	18.86	18.26	17.68	17.23	16.80
1300	24.76	23.70	22.77	21.88	21.10	20.43	19.73	19.16	18.67	18.20
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## WEIGHTS AND MEASURES.

Table 56.—*Miscellaneous.*

Basalt .. .. .	187 lb. per cub. ft.		
Clay .. .. .	100 "	"	28 cub. ft. = 1 ton.
Clay slate .. .. .	180 "	"	
Coal, anthracite .. .. .	50-55 "	"	
" " broken, 1 cub. ft. =	1.75 cub. ft.		
" bituminous .. .. .	40-50 lb. per cub. ft.		
" " .. .. .	70-78 "	heaped bushel.	
" " Cannel .. .. .	50 "	cub. ft.	
" " Cumberland .. .. .	53 "	"	
" " Lancashire .. .. .	44 cub. ft. = 1 ton.		
" " Newcastle .. .. .	45 "	"	
" " R.N. allowance .. .. .	48 "	"	
" " Scotch .. .. .	43 "	"	
" " Welsh .. .. .	43 "	"	
Gravel, coarse .. .. .	23 "	"	
" free from cement and containing			
" no heavy boulders, wet .. .. .	90-100 lb. per cub. ft.		
" ditto do. dry .. .. .	80-90 "	"	
" boulders not over 6 in. diameter, wet	95-105 "	"	
" ditto do. do. dry .. .. .	85-95 "	"	
" 18 cub. ft. in bank = 27 cub. ft. dry =	1 ton.		
Limestone, solid .. .. .	170 lb. per cub. ft.		
" broken .. .. .	96 "	"	
Loam, wet, loose .. .. .	72-80 "	"	
" " packed .. .. .	90-100 "	"	
" dry, loose .. .. .	66-68 "	"	
" " packed .. .. .	85-95 "	"	
Loose dirt, about 400 cub. in. to a miners' pan.			
Quartz, solid .. .. .	165 "	"	
" broken .. .. .	94 "	"	
Sand, dry .. .. .	88-90 "	"	
" wet .. .. .	118-120 "	"	
Shale .. .. .	162 "	"	
" decomposed .. .. .	100 "	"	
Traprock .. .. .	170 "	"	
Wood, 4 ft. × 4 ft. × 8 ft. = 128 cub. ft. = 1 cord.			
" charcoal, 18 lb. per cub. ft., 124½ cub. ft. = 1 ton.			

—	Sp. gr.	Lb. per cub. ft.	—	Sp. gr.	Lb. per cub. ft.
Alabaster, white ..	2730	170·625	Earth, loose ..	1500	93·75
„ yellow ..	2699	168·687	„ moist sand ..	2050	128·125
Alum .. .. .	1714	107·125	„ mould, fresh ..	2050	128·125
Amber .. .. .	1078	67·375	„ rammed ..	1000	100
Asbestos, starry ..	3073	192·062	„ rough sand ..	1920	120
Asphalte .. ..	2250	140·625	„ with gravel ..	2020	126·25
Barytes, sulphate {	4000	250	„ potters' ..	1900	118·75
„ {	4865	304·062	„ light vegetable ..	1400	87·5
Basalt .. .. .	2740	171·25	Emery .. .. .	4000	250
„ {	2864	179	Felspar .. .. .	2600	162·5
Bitumen, red .. ..	1160	72·3	Flint, black .. ..	2582	161·375
„ brown .. .. .	830	51·7	„ white .. .. .	2594	162·125
Borax .. .. .	1714	107·125	Fluorine .. .. .	1320	82·5
Brick .. .. .	1367	85·437	Fuel, Warlich's ..	1150	71·875
„ {	1900	118·75	„ Lignite .. .. .	1300	81·25
„ pressed .. .. .	2100	150	Gneiss, common ..	2700	158·75
„ fire .. .. .	2201	137·562	Granite, Egyptian red	2654	165·875
„ work in cement {	1800	112·5	„ Patapasco .. ..	2610	165
„ {	1600	100	„ Quincy .. .. .	2652	165·75
„ „ mortar {	2000	125	„ Scotch .. .. .	2625	164·062
Carbon .. .. .	3560	218·75	„ Susquehanna ..	2704	169
Cement, Portland ..	1300	81·25	„ „ grey .. .. .	2800	175
„ Roman .. .. .	1560	97·25	Graphite .. .. .	2200	137·5
Chalk .. .. .	1520	95	Gravel, common ..	1749	100
„ {	2781	174	Grindstone .. ..	2143	133·937
Clay .. .. .	1930	120	Gypsum, opaque ..	2168	135·5
„ with gravel .. ..	2480	155	Hone, white, razor ..	2876	179·75
Coal, Anthracite ..	1350	84·375	Hornblende .. ..	3500	221·25
„ {	1436	89·75	Iodine .. .. .	4940	—
„ {	1640	102·5	Lava, Vesuvius .. {	1710	106·875
„ Borneo .. .. .	1290	80·625	„ {	2810	175·625
„ Cannel .. .. .	1238	77·375	Lias .. .. .	1350	146·875
„ {	1318	82·575	Lime, quick .. ..	804	50·25
„ Caking .. .. .	1277	79·812	„ hydraulic .. ..	2745	171·562
„ Cherry .. .. .	1276	79·75	„ Limestone, white ..	3166	197·25
„ Chili .. .. .	1290	80·625	„ green .. .. .	3180	198·75
„ Derbyshire .. ..	1292	80·75	Magnesia, carbonate	2400	150
„ Lancaster .. ..	1273	79·562	Magnetic ore .. ..	5094	317·6
„ Maryland .. ..	1355	84·687	Marble, Adelaide ..	2715	169·687
„ Newcastle .. ..	1270	79·375	„ African .. .. .	2704	169·25
„ Rive de Gier .. ..	1300	81·25	„ Biscayan, black ..	2695	168·437
„ {	1259	78·687	„ Carrara .. .. .	2716	169·75
„ Scotch .. .. .	1300	81·25	„ common .. .. .	2686	167·875
„ Splint .. .. .	1302	81·375	„ Egyptian .. ..	2668	166·75
„ Wales, mean .. ..	1315	82·187	„ French .. .. .	2649	165·562
Coke .. .. .	1000	62·5	„ Italian, white ..	2708	169·25
„ „ Nat'l, Va. .. ..	746	46·64	„ Parian .. .. .	2838	177·375
Concrete, in cement ..	2200	137·5	„ Silesian .. .. .	2730	170·625
„ mean .. .. .	2000	125	„ Vermont, white ..	2650	165·57
Earth, common soil, ..			„ Marl, mean .. ..	1750	109·375
dry .. .. .	1216	76	„ tough .. .. .	2340	146·25

Table 57—continued.

—	Sp. gr.	Lb. per cub. ft.	—	Sp. gr.	Lb. per cub. ft.
Masonry, rubble ..	2050	128·125	Sand, mortar, Ft. Rich-		
„ Granite ..	2640	165	mond ..	1659	103·66
„ Limestone ..	2640	165	„ „ Brooklyn ..	1716	107·25
„ Sandstone ..	2160	135	„ „ silicious ..	1701	106·33
„ Brick ..	2240	140	Sandstone, mean ..	2200	137·5
„ „ rough-			„ Sydney ..	2237	139·81
work ..	1600	100	Schorl ..	3170	198·125
Mica ..	2900	175	Scoria, volcanic ..	830	51·875
Millstone ..	2484	155·25	Shale ..	2600	162·5
„ Quartz ..	1260	78·75	Slate ..	2672	167
	1384	86·5	„ „ ..	2900	181·25
Mortar ..	1750	109·375	„ purple ..	2784	174
Mud ..	1630	101·875	Smalt ..	2440	152·5
„ wet and fluid ..	1782	112	Soapstone ..	2730	170·625
„ „ „ pressed ..	1920	120	Spar, calcareous ..	2735	170·937
Nitre ..	1900	118·75	„ feld, blue ..	2693	168·312
Paving-stone ..	2416	151	„ „ green ..	2704	169
Peat, Irish, light ..	278	17·375	„ fluor ..	3400	212·5
„ „ dense ..	562	35·125	Specular ore ..	5251	328·187
„ „ very dense ..	675	42·187	Stalactite ..	2415	150·937
„ black ..	1058	66·125	Stone, Bath ..	1961	122
	1329	83·062	„ Blue Hill ..	2640	165
Phosphorus ..	1770	110·625	„ Bluestone (ba-		
Plaster of Paris ..	1176	73·5	salt) ..	2625	164·062
„ „ dry ..	3400	212·5	„ Breakneck, N.Y. ..	2704	169
„ „ „ ..	1400	87·5	„ Bristol ..	2510	156·875
Porcelain, China ..	2300	143·75	„ Caen, Normandy ..	2076	129·75
Porphyry, red ..	2765	172·812	„ common ..	2520	157·5
Pumice ..	915	57·187	„ Craigleith ..	2316	144·75
Quartz ..	2660	166·25	„ Kentish rag ..	2651	165·687
Red lead ..	8940	558·75	„ Kip s Bay, N.Y. ..	2759	172
Rock, crystal ..	2735	170·937	„ Norfolk (Par-		
Rotten-stone ..	1981	123·812	liament House) ..	2304	144
Salt, common ..	2130	133·125	„ Portland ..	2368	148
„ rock ..	2200	137·5	„ Staten Island,		
Saltpetre ..	2090	130·625	N.Y. ..	2976	186
Sand, coarse ..	1800	112·5	„ Sullivan Co. ..	2688	168
„ common ..	1670	104·375	Sulphur, native ..	2033	127·062
„ damp and loose ..	1392	87	Terra cotta ..	1952	122
„ dried ..	1560	97·5	Tile ..	1815	113·437
„ dry ..	1420	88·75	Trap ..	2720	170

Table 58.—WEIGHTS AND MEASURES: *Precious Stones.*

	Sp. gr.		Sp. gr.		Sp. gr.
Agate ..	2595	Emerald, aqua ma-		Onyx ..	2700
Amethyst ..	2620	rine ..	2730	Opal ..	2090
Carnelian ..	2613	Garnet ..	4189	Pearl, Oriental ..	2650
Chrysolite ..	2782	„ black ..	3750	Ruby ..	3980
Diamond, Oriental ..	3521	Jasper ..	2600	Sapphire ..	3994
„ „ Brazilian ..	3444	Jet ..	1300	Topaz ..	3500
„ „ pure ..	3550	Lapis lazuli ..	2950	Tourmaline ..	2970
Emerald ..	2750	Malachite ..	4020	Turquoise ..	2750

Table 59.—WEIGHTS AND MEASURES: *Metals.* (Haswell.)

—	Sp. gr.	Lb. per cub. in.	—	Sp. gr.	Lb. per cub. in.
Aluminium, cast ..	2560	•0926	Iron, wrought, pure..	8140	•2938
„ wrought ..	2670	•0906	„ ordinary mean..	7744	•2801
„ bronze ..	7700	•2.85	Lead, cast ..	11352	•4106
Antimony .. ..	6712	•2488	„ rolled .. ..	11388	•4119
Arsenic .. ..	5763	•2084	Lithium .. ..	590	•0213
Barium .. ..	470	•017	Magnesium .. ..	1750	•0633
Bismuth .. ..	9823	•3553	Manganese .. ..	8000	•2894
Boron .. ..	2000	•0723	Mercury — 40° ..	15632	•5661
Brass—			„ + 32° .. ..	13598	•4918
Sheet, cop 75, zinc 25	8450	•3056	„ + 60° .. ..	13569	•4908
Yellow „ 66, „ 34	8300	•2997	„ + 212° .. ..	13370	•4836
Muntz „ 60, „ 40	8200	•2966	Molybdenum .. ..	8600	•3111
Plate .. ..	8380	•3026	Nickel .. ..	8800	•3183
Cast .. ..	8100	•2930	„ cast .. ..	8279	•2994
Wire .. ..	8214	•2972	Niobium .. ..	6000	•217
Bromine .. ..	3000	•1085	Osmium .. ..	10000	•3613
Bronze, gun metal ..	8750	•3165	Palladium .. ..	11350	•4105
„ ordinary mean	8217	•2972	Platinum, hammered	20337	•7356
„ cop, 84, tin 16	8832	•3194	„ native .. ..	16000	•5787
„ „ 81, „ 19	8700	•2929	„ rolled .. ..	22069	•7982
„ small bells,			Potassium, 59° ..	865	•0313
cop. 35, tin 65	8060	•291	Red lead .. ..	8940	•324
„ „ 21, „ 74	7390	•2668	Rhodium .. ..	10650	•3852
Cadmium .. ..	8650	•3120	Rubidium .. ..	1520	•055
Calcium .. ..	1580	•057	Ruthenium .. ..	8600	•3111
Chromium .. ..	5900	•2134	Selenium .. ..	4500	•1627
Cinnabar .. ..	8098	•2929	Silver, pure, cast ..	10474	•3788
Cobalt .. ..	8600	•3111	„ „ hammered	10311	•3802
Columbium .. ..	6000	•217	Sodium .. ..	970	•0351
Copper, cast .. ..	8788	•3179	Steel, minimum ..	7700	•2785
„ plates .. ..	8698	•3146	„ maximum .. ..	7900	•2857
„ wire and bolts	8880	•3212	„ plates, mean ..	7806	•2823
„ ordinary mean	8880	•3212	„ soft .. ..	7833	•2833
Gold, pure, cast ..	19258	•6965	„ tempered and		
„ hammered .. ..	19361	•7003	„ hardened .. ..	7818	•2828
„ 22 carats fine ..	17486	•6325	„ wire .. ..	7847	•2838
„ 20 „ „ ..	15709	•5682	„ blistered .. ..	7823	•283
Iridium .. ..	18680	•6756	„ crucible .. ..	7842	•2836
„ hammered .. ..	23000	•8319	„ cast .. ..	7848	•2839
Iron, cast .. ..	7308	•264	„ Bessemer .. ..	7852	•284
„ minimum .. ..	6900	•2491	„ ordinary mean	7834	•2916
„ maximum .. ..	7500	•2707	Strontium .. ..	2540	•0918
„ ordinary mean..	7207	•2607	Tellurium .. ..	6110	•221
„ mean, Eng. ..	7217	•2609	Thallium .. ..	11850	•4286
„ cast, hot blast ..	7065	•2555	Tin, Cornish, hamm'd	7390	•2673
„ „ cold .. ..	7218	•2611	„ pure .. ..	7291	•2637
„ wrought bars ..	7788	•2817	Titanium .. ..	5300	•1917
„ „ wire .. ..	7774	•2811	Tungsten .. ..	17000	•6149
„ „ roll'd pl't's	7704	•2787	Uranium .. ..	18330	•6629
„ „ average ..	7698	•2779	Wolfram .. ..	7119	•2575
„ „ Eng. rails	7540	•2722	Zinc, cast .. ..	6861	•2482
„ „ Lowmoor	7808	•2819	„ rolled .. ..	7191	•26

Table 60.—WEIGHTS AND MEASURES: *Metals* (Molesworth).

## Wrought Iron.

Cubic inches	×	·28	=	lb. avoirdupois.
"	×	100	=	qr.
"	×	400	=	cwt.
Thickness of plates in inches	×	40	=	lb. per sq. ft.
"	"	eighths	×	5 = " "
"	"	tenths	×	4 = " "
Sectional area in inches	×	3·34	=	lb. per lin. ft.
"	"	eighths	×	·052 = " "
"	"	inches	×	10 = lb. per lin. yd.
Lb. per lineal yard	×	·7857	=	tons per mile run.
Diameter of round iron in inches squared	×	2·64	=	lb. per foot run.

## Various Metals.

Multipliers to convert the weights as found above into the weights of other metals.

Weight of wrought iron	×	·92	=	weight of zinc.
"	"	"	×	·93 = " cast iron.
"	"	"	×	·94 = " tin.
"	"	"	×	1·02 = " steel.
"	"	"	×	1·09 = " brass.
"	"	"	×	1·15 = " copper.
"	"	"	×	1·47 = " lead.
Cub. in.	"	"	×	·252 = lb. of zinc.
"	"	"	×	·26 = " cast iron.
"	"	"	×	·262 = " tin.
"	"	"	×	·288 = " steel.
"	"	"	×	·3 = " brass.
"	"	"	×	·32 = " copper.
"	"	"	×	·41 = " lead.

A bar of wrought iron 1 × 1 and 1 yd. long weighs 10 lb.

## Rule for Weight of Pipes.

D	=	Outside diameter of pipe in inches.
d	=	Inside diameter.
w	=	Weight of a lineal foot of pipe in lb.
w	=	$k(D^2 - d^2)$ .
k	=	2·45 for cast iron.
	=	2·64 for wrought iron.
	=	2·82 for brass.
	=	3·03 for copper.
	=	3·86 for lead.



Table 61.—*Mexican Mining Weights.*

1 grano	=	·7716	gr.
12 granos	=	1 tomin	= 9·2592 "
6 tomines	=	1 ochava	= ·12685 oz.
8 ochavas	=	1 onza	= 1·0148 "
8 onzas	=	1 marco	= 8·1184 "

The *marco* is the unit for weighing bullion.

Mexicans value an ore at so many *marcos* of silver per *carga*, instead of oz. per ton.

The *carga* = 12 *arrobas* = 304·332 lb.

To reduce *onzas* per *carga* to oz. per ton, multiply by 6·078; and to convert oz. per ton to *onzas* per *carga*, multiply by ·165.

The <i>monton</i> in Zacatecas	=	20 quintals	=	2000 lb.
"	"	Guanajato	=	3200 "
"	"	some places	=	3000 "
"	"	others	=	4 <i>cargas</i> = 1200 "

Table 62.—*Surveying Measures.*

Circle, diameter	× 3·1416	=	circumference.
"	× ·8862	=	side of an equal square.
"	× ·7071	=	side of an inscribed square.
" area = diameter <sup>2</sup>	× ·7854.		
" circumference	× ·31831	=	diameter.
Circular inches	× 183,346	=	1 sq. ft.
Sphere, diameter <sup>3</sup>	× ·5236	=	solidity.
" diameter	× ·806	=	dimensions of equal cube.
"	× ·6667	=	length of equal cylinder.
Cylindrical inches	× ·0004546	=	cub. ft.
"	× ·002832	=	gal.
"	2200	=	1 cub. ft.
" feet	× ·02909	=	cub. yd.
Square, side	× 1·128	=	diameter of an equal circle.
" root of acre	× 1·12837	=	diameter of an equal circle.
" inches	× ·00695	=	sq. ft.
" feet	× ·0000229	=	acres.
" yards	× ·0002066	=	acres.
Cubic inches	× ·00058	=	cub. ft.
" feet	× ·03704	=	cub. yd.
"	× ·6232	=	gal.
Lineal feet	× 1·51515	=	links.
"	× ·00019	=	miles.
" yards	× 4·54545	=	links.
"	× ·000568	=	miles.
" links	× ·66	=	ft.
"	× ·22	=	yd.
" chains	× ·0125	=	miles.

Table 62—*continued*.

Lineal miles	$\times 5,280$	= ft.
" "	$\times 1,760$	= yd.
" "	$\times 80$	= chains.
Acres	$\times 43,560$	= sq. ft.
"	$\times 4,840$	= sq. yd.
Area of circle = diameter <sup>2</sup> $\times .7854$ .		
"	parallelogram = base $\times$ height.	
"	trapezium: divide into two triangles and find area of each.	
"	trapezoid = height $\times \frac{1}{2}$ the sum of the parallel sides.	
"	triangle = base $\times \frac{1}{2}$ height.	
Latitude (northing or southing) = cos. of angle of bearing $\times$ distance.		
Departure (eastings or westings) = sin. of angle of bearing $\times$ distance.		
Level, difference of = sin. of angle of inclination $\times$ hypotenuse.		
Horizontal measurement = cos. of angle of inclination $\times$ hypotenuse.		
Inclination, rate of (ratio of base to perpendicular) = cotan. of angle of inclination.		
Slope, rate of (ratio of hypotenuse to perpendicular) = cosec. of angle of inclination.		

Table 63.—*Areas of Circles.*

Diam.	Area.	Diam.	Area.	Diam.	Area.	Diam.	Area.	Diam.	Area.
in.	sq. in.	in.	sq. in.	in.	sq. in.	in.	sq. in.	in.	sq. in.
$\frac{1}{8}$	.012	$7\frac{1}{8}$	44.17	20	314.16	$32\frac{1}{8}$	829.5	45	1590.4
$\frac{1}{4}$	.049	8	50.26	$20\frac{1}{8}$	330.06	33	855.3	$45\frac{1}{8}$	1625.9
$\frac{3}{8}$	.110	$8\frac{1}{8}$	56.74	21	346.36	$33\frac{1}{8}$	881.4	46	1661.9
$\frac{1}{2}$	.196	9	63.61	$21\frac{1}{8}$	363.05	34	907.9	$46\frac{1}{8}$	1698.2
$\frac{5}{8}$	.441	$9\frac{1}{8}$	70.88	22	380.13	$34\frac{1}{8}$	934.8	47	1734.9
1	.785	10	78.54	$22\frac{1}{8}$	397.60	35	962.1	$47\frac{1}{8}$	1772.0
$1\frac{1}{8}$	.994	$10\frac{1}{8}$	86.59	23	415.47	$35\frac{1}{8}$	989.8	48	1808.5
$1\frac{1}{4}$	1.227	11	95.03	$23\frac{1}{8}$	433.73	36	1017.8	$48\frac{1}{8}$	1847.4
$1\frac{3}{8}$	1.767	$11\frac{1}{8}$	103.87	24	452.39	$36\frac{1}{8}$	1046.3	49	1885.7
$1\frac{1}{2}$	2.405	12	113.10	$24\frac{1}{8}$	471.43	37	1075.2	$49\frac{1}{8}$	1924.4
2	3.141	$12\frac{1}{8}$	122.71	25	490.8	$37\frac{1}{8}$	1104.4	50	1963.5
$2\frac{1}{8}$	3.976	13	132.73	$25\frac{1}{8}$	510.7	38	1134.1	$50\frac{1}{8}$	2002.9
$2\frac{1}{4}$	4.908	$13\frac{1}{8}$	143.13	26	530.9	$38\frac{1}{8}$	1164.1	51	2042.8
$2\frac{3}{8}$	5.939	14	153.94	$26\frac{1}{8}$	551.5	39	1 94.6	$51\frac{1}{8}$	2083.0
3	7.06	$14\frac{1}{8}$	165.13	27	572.5	$39\frac{1}{8}$	1225.4	52	2123.7
$3\frac{1}{8}$	8.29	15	176.71	$27\frac{1}{8}$	593.9	40	1256.6	$52\frac{1}{8}$	2164.7
$3\frac{1}{4}$	9.62	$15\frac{1}{8}$	188.69	28	615.7	$40\frac{1}{8}$	1288.2	53	2206.1
$3\frac{3}{8}$	11.04	16	201.06	$28\frac{1}{8}$	637.9	41	1320.2	$53\frac{1}{8}$	2248.0
4	12.56	$16\frac{1}{8}$	213.82	29	660.5	$41\frac{1}{8}$	1352.6	54	2290.2
$4\frac{1}{8}$	15.90	17	226.98	$29\frac{1}{8}$	683.4	42	1385.4	$54\frac{1}{8}$	2332.8
5	19.63	$17\frac{1}{8}$	240.52	30	706.8	$42\frac{1}{8}$	1418.6	55	2375.8
$5\frac{1}{8}$	23.76	18	254.46	$30\frac{1}{8}$	730.6	43	1452.2	$55\frac{1}{8}$	2419.2
$5\frac{1}{4}$	28.27	$18\frac{1}{8}$	268.80	31	754.7	$43\frac{1}{8}$	1486.1	56	2463.0
$6\frac{1}{8}$	33.18	19	283.53	$31\frac{1}{8}$	779.3	44	1520.5	$56\frac{1}{8}$	2507.1
7	38.48	$19\frac{1}{8}$	298.64	32	804.2	$44\frac{1}{8}$	1555.2	57	2551.7

## PROSPECTING.

These notes refer chiefly to gold, but embrace other metals and such gems as are found in alluvial formations.

*Streams.*—As a rule, those streams which cross the laminations of reefs at right angles, or nearly so, are the richest. Gold is found very rarely in those parts of streams where the current has been the strongest, but generally in the lee or under the shelter of projecting points of rocks, where beaches are usually formed; and wherever such beaches exist there also may gold be looked for with fair chances of success. But the straight courses of streams, especially when they cross the laminations of the bed-rock at right angles, are also often very rich in gold. As a rule, the gold in streams is deposited in the crevices of the bed-rock, which must be laid as dry as possible, and picked up to such depths as the sand descends between its laminations. Very rarely is the gold found mixed up in the gravel lying in the beds of streams.

*Terraces.*—Terrace prospecting requires more experience, labour, perseverance, and, consequently, more time than creek prospecting. Terraces are those shelf-like excavations upon the hill-slopes flanking valleys and lakes, and are the remains of old river-beds; so that the rules above laid down for the deposition of gold in streams apply also to terraces. Sometimes a ridge of rock divides a terrace from the newer river-channel, but this is not always the case. The first thing to do in prospecting a terrace is to discover its inlet, and next to find its outlet. This found, the "wash" should be carefully examined for the prevailing indications of gold peculiar to the locality in which the terrace occurs, and also for gold. The whole width of the channel of the terrace from the edge to the high or back reef must be carefully prospected, both along the bed-rock and also through the whole depth of the "wash," from the surface down; for the terrace "wash," being often deposited at different geological times, not unfrequently contains gold in layers one above the other. These terraces are very numerous in New Zealand; and a study of the river systems of the present, as well as of the preceding geological ages, will assist the prospector greatly in his choice of a likely spot where to set in. There is a general fall in the country lying along the main directions of the present streams, which indicates the leading course upon which all alluvial gold has been deposited, the consideration of which is often a reliable guide to the level of terraces which are covered up completely by landslips, or in which either the inlet or the outlet is hid from view. In New Zealand large fortunes lie buried in many locations thus hid, :

*Terraces—continued.*

require a great amount of prospecting to unearth ; so that prospectors have an extensive field before them in this direction.

*Table-lands.*—The gold found at these elevations belongs to a different geological age from the gold generally obtained in New Zealand. This opinion is supported by the nature of the wash in which the table-land gold is found, nothing like it being met with on lower levels. In looking for new deposits of this description, the prospector should not be deterred by the elevation of any table-land, for gold in really astonishing quantities has been got at Mount Criffel, upwards of 4000 ft., and at Mount Pisa, nearly 6000 ft. above sea-level. Nor need much attention be paid to the "wash" in these places: and, indeed, its total absence does not necessarily imply the absence of gold. As a rule, the sinking upon these table-lands is shallow and easy, and often the gold is distributed evenly throughout the body of the "wash," or else occurs in layers one above the other, as well as upon the bed-rock. So far as discovered, these deposits occur upon mountain-tops bordering the principal Otago goldfields, rather than upon those in their midst, the gold being found deposited in a somewhat erratic manner.

*Beach-workings.*—Beach-workings may receive a passing notice, as the ocean beaches of the Middle Island have contributed considerable quantities of gold to the total yield of the colony. And the same may be said of dredging the larger rivers—an enterprise often highly remunerative. Both descriptions of gold-raising are capable of much extension and improvement. (Miller.)

*Vein Outcrops.*—Whilst working up the stream, attention must be paid to the banks on each side, especially where they show a section of the rocks, so that no outcropping vein may be overlooked. Should a quartzose or pyritous vein be discovered, specimens must be broken down for examination.

As all alluvial gold is the result of the breaking up of auriferous veins, an effort should always be made to trace the former to its source. Many valuable reefs have been found in this way. The occurrence of "float," or stray pieces of quartz, if of a promising appearance, should be taken as a guide also. Obviously, some judgment is necessary in estimating the best direction for search, and in determining the drainage area to which the float belongs. Sometimes there may be much difficulty in locating the reef, owing to disturbances or to accumulation of detritus hiding the nature of the subjacent rock. A knowledge of the neighbouring reefs and their gold is of great assistance. Where the gold specks and pebbles are much worn, they may represent a former riverine deposit, or its remains, scattered far from its previous resting-place. Where the gold is heavy and the rock fragments are angular, the reef cannot be very far distant. Occasionally there may be a distinct feature in all the veins in a district, such as a peculiar band of defined colour, and the recurrence of this indicator should

*Veins—continued.*

then stimulate search for the accompanying reef. Coarse alluvial gold is not always incompatible with fine reef gold as a source, because the reef gold may be so fine in general as to lend itself to very wide distribution when once liberated, while the rarer coarse grains would not be transported far.

Much intelligent prospecting for auriferous reefs is done by "loaming," as a preliminary to cutting experimental trenches or sinking trial shafts. Loaming, long practised in searching for tin in Cornwall, consists in washing surface prospects from the bases and slopes of the ranges, until specks of gold or specimens are found to be obtainable with tolerable frequency within certain limits. The prospector then proceeds to trace the gold up-hill to its source, narrowing the limits of his work, as by slow and patient search he approaches the reef whence the gold has been derived. When he finds that he can obtain surface prospects of gold up to a certain point or line, but no farther, he then proceeds by means of trenching, &c., to search for the reef. As may be imagined, the work is one requiring patience, energy, and insensibility to fatigue, together with good memory for locality, as the prospector frequently has to work along a steep and scrubby mountain side, selecting his prospects, numbering them, and placing them in his "loam-bag," noting the localities, and then conveying his samples many hundred feet down the ranges to water. If he be fortunate in obtaining prospects of gold, he has to find his way back to the spots the samples were taken from, so as to continue his up-hill search, and trace the gold to its matrix. In many new discoveries made by means of the above system there was no surface indication whatever of the existence of a reef; nothing visible to the eye that would have led one passing over the ground to believe that it was there, the soil and debris completely concealing its outcrop, until by means of "loaming," the prospector was enabled so nearly to ascertain its position as to expose it in a trench of not many feet in length.

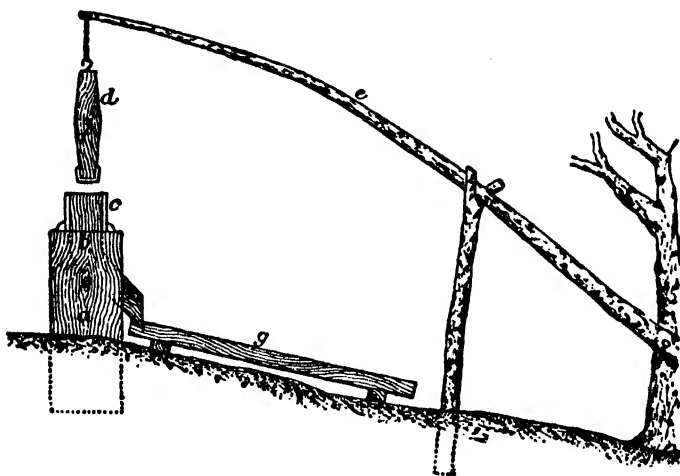
*Prospecting Stamps.*—In order to obtain proper samples of the vein-stuff for testing, it is necessary to reduce it to a fine state of subdivision, such as is ordinarily accomplished in the stamp battery.

A primitive yet efficient apparatus for this purpose, and such as may be erected by the prospector himself without the aid of much engineering skill, is shown in Fig. 9, and goes by the name of a "dolly." On the end of a solid log *a*, fixed in the ground and standing about 4 ft. high, is cut a square hole *b*, about 6 in. across, in which are firmly fitted wrought-iron bars about  $\frac{1}{2}$  in. apart,  $\frac{1}{2}$  in. thick and 3 in. deep, made thinner beneath, so that whatever enters above will fall through. A wooden box *c* is placed round this to keep the ore from jumping away. A square block of wood *d*, about 3 or 4 ft. long, shod with wrought iron, and small enough at the lower end to work in the box, forms the stamper. It is hung on the end of a long pole *e*, the spring of which keeps it on

*Stamps*—continued.

the swing without too much labour. It is worked by laying hold with the hands of a wooden pin *f* on each side of the stamper, and pulling it down, its own rebound and the spring of the pole taking

Fig. 9.



Dolly, or Prospecting Stamp.

it up again. The iron bars might be replaced by an old stamp die. The gold is caught on the table *g*, which is covered with amalgamated copper plate or blanket.

Table 64.—PROSPECTING: *Boring.*

Cost of some trial borings for ironstone in the Barrow district, made with the aid of a steam winch and free-falling tool:—

Depth of Hole.	Diameter of Hole.	Cost per yd.	Cost of Labour alone.	Time occupied.
yd.	in.	s. d.	£ s. d.	weeks
126	6 to 2	7 10½	49 10 0	15
124*	"	9 7	59 8 0	18
50	"	9 10½	24 15 0	7½
63	"	9 5	29 14 0	9
76½	"	6 0½	23 2 0	7
88	"	8 3	36 6 0	11
48	"	11 0	26 8 0	8

\* The strata passed through in this hole were as follows, proceeding from the surface downwards:—45 ft. pinder, 75 ft. red sand, 3 ft. white sand, 30 ft. red sand mixed with clay, 150 ft. red sand, 30 ft. red and white sand, 6 ft. white sand, 6 ft. shale, 4 ft. ore, 6 ft. clay, 1 ft. ore, 2 ft. stone, 9 ft. ore, 2 ft. black shale, 3 ft. stone—total, 372 ft.

Table 65.—Approximate cost per set of boring tools, including rigger, rope, and ordinary shear legs, and windlass for depths of 300 ft. and upwards:—

To bore 30 ft.	.. .. .	20	To bore 250 ft.	.. .. .	£
„ 50	„ .. .. .	36	„ 300	„ .. .. .	120
„ 100	„ .. .. .	45	„ 500	„ .. .. .	155
„ 150	„ .. .. .	58	„ 800 to 1000 ft...		195
„ 200	„ .. .. .	70			

## TOOLS.

TOOLS: *Picks.*

- Holing pick, S. Wales: head straight, length 18 in.; helve,  $33\frac{1}{2}$  in. long; weight,  $3\frac{1}{2}$  lb.
- Cutting pick, S. Wales: head straight, length 17 in.; helve,  $20\frac{1}{2}$  in. long; weight, 2 lb. 14 oz.
- Bottom pick, S. Wales: head,  $21\frac{1}{4}$  in. long; helve,  $30\frac{1}{2}$  in. long; weight, 3 lb. 3 oz.
- Stone pick: head, 24 in. long; helve,  $30\frac{1}{2}$  in. long; weight, 9 lb. 5 oz.
- Holing pick, N. Wales: head, 18 in. long; helve, 28 in. long; weight, 2 lb. 10 oz.
- Heading pick, N. Wales: head,  $16\frac{1}{4}$  in. long; helve,  $27\frac{1}{2}$  in. long; weight, 3 lb.
- Driving pick: head,  $17\frac{1}{4}$  in. long; helve,  $27\frac{1}{2}$  in. long; weight, 3 lb. 10 oz.
- Coal pick, N. England: head,  $17\frac{1}{2}$  in. long; helve, 32 in. long; weight, 4 lb. 5 oz.
- Coal pick, N. England: head, 18 in. long; helve, 32 in. long, angle  $155^{\circ}$ ; weight, 4 lb. 5 oz.
- Stone pick, N. England: head,  $19\frac{1}{4}$ –23 in. long; helve, 30 in. long; weight 7–8 lb.
- Poll pick, Cornwall: pick end  $12\frac{1}{2}$  in. long, poll end 3 in. long, eye 2·2 in. long, width over eye 3·1 in., width of poll end 1·2 in., width of pick end 1·1 in., thickness of poll end 1·2 in., thickness of pick end 1·1 in.; helve, 26 in. long, set at  $85^{\circ}$ ; weight,  $8\frac{1}{2}$  lb.
- Slitter pick: head, 15·7 in. long; handle, 29 in. long; weight, 3 lb. 10 oz.
- Drifting pick, California: weight,  $3\frac{1}{2}$ –4 lb.
- Poll pick, California: head,  $16\frac{1}{2}$  in. long; weight, 5 lb.
- Helves, 1s. 6d. each. Heads, 8d. to 9d. per lb.

TOOLS: *Shovels.*

- Gravel shovel: plate, 10 in. wide, mouth pointing; handle, 30 in. long, set at angle of  $150^{\circ}$ . Cost (10–12 in. wide), 25–35s. a doz.; steel, 60–70s.
- Frying-pan filling shovel: plate nearly circular, 14 in. wide, 16 in. long; handle, 24 in. long, set at  $142^{\circ}$ ; weight, 7 lb. 14 oz. Cost, 35–48s. a doz.
- Round-mouthed filling shovel: plate 16 in. wide, 15 in. long; handle, 23 in. long, set at  $147^{\circ}$ ; weight, 7 lb. 14 oz. Cost, 35–48s. a doz.; steel, 45–60s.
- Sinking shovel: pointed plate,  $11\frac{1}{2}$  in. by 14 in.; handle, 23 in. long.



TOOLS: *Wedges.*

Coal wedge, S. Wales: length,  $13\frac{1}{4}$  in.; central section, breadth  $1\frac{1}{4}$  in., thickness  $\frac{7}{8}$  in.; striking face, breadth  $1\frac{1}{8}$  in., thickness 1 in.; weight 3 lb. 14 oz.

Coal wedge, N. Wales: length  $11\frac{1}{2}$  in.; greatest section, breadth  $1\frac{3}{4}$  in., thickness  $\frac{7}{8}$  in.; weight 3 lb. 9 oz.

Coal wedge, N. England: length 12 in. greatest section.

TOOLS: *Hammers.*

*Sledges.*—Eye generally oval. Weight of head 5–10 lb., most commonly 7 lb. Length of helve 20–30 in., usually 24 in. for blasting, 28 in. for wedge-driving. For coal wedging, the head is generally 12 in. long and  $2\frac{1}{4}$  in. max. diam., tapering to  $1\frac{1}{2}$  in.

South Wales blasting sledge: head,  $8\frac{3}{4}$  in. long, helve 27 in.; total weight 7 lb. North Wales ditto: head  $7\frac{3}{4}$  in. long, helve 22 in.; weight  $6\frac{1}{2}$  lb. North of England sledge: head 5 in. long, helve  $24\frac{1}{2}$  in.; weight under 5 lb.

*Hand hammers* usually have a head weighing about 3 lb., and a helve 10 in. long.

TOOLS: *Drills.*

The edge of the drill may be straight, as in the flat chisel for deep drilling, or slightly curved. The straight edge cuts its way somewhat more freely than the curved, but it is weaker at the corners than the curved, a circumstance which renders it less suitable for very hard rock. It is also slightly more difficult to forge. The width of the bit varies, according to the width required, from 1 to  $2\frac{1}{2}$  in. The stock is octagonal in section, and is made in lengths varying from 20 to 42 in. The shorter the stock, the more effectively does it transmit the blow, and therefore it is made as short as possible: for this reason several lengths are employed in drilling a blast-hole, the shortest being used at the commencement of the hole, a longer one to continue the depth, and a still longer one, sometimes, to complete it. To ensure the longer drills working freely in the hole, the width of the bit should be very slightly reduced in each length. The diameter of the stock is less than the width of the bit; this difference may be greater in coal drills than in rock or "stone" drills; a common difference in the latter is  $\frac{3}{8}$  in. for the smaller sizes, and  $\frac{1}{2}$ – $\frac{3}{4}$  in. for the longer. The following proportions may be taken as the average adopted:—

Width of the Bit.		Diameter of the Stock.	Width of the Bit.		Diameter of the Stock.
1 in.	.. .. .	$\frac{7}{8}$ in.	$1\frac{1}{4}$ in.	.. .. .	$1\frac{1}{8}$ in.
$1\frac{1}{8}$ "	.. .. .	$\frac{3}{4}$ "	2 "	.. .. .	$1\frac{1}{4}$ "
$1\frac{1}{4}$ "	.. .. .	$\frac{7}{8}$ "	$2\frac{1}{4}$ "	.. .. .	$1\frac{1}{2}$ "
.. .. .	.. .. .	1 "	$2\frac{1}{2}$ "	.. .. .	$1\frac{3}{4}$ "

The striking face of the drill should be flat. The diameter of the face is less than that of the stock in all but the smallest sizes,

*Drills—continued.*

the difference being made by drawing in the striking end. The amount of reduction is greater for the larger diameters, that of the striking face being rarely more than  $\frac{1}{8}$  in.

TOOLS: *Hand-drilling Gears.*

A set of single coal-blasting gear will include a drill, 22 in. long, with cutting edge straight and  $1\frac{1}{2}$  in. wide, and weight  $2\frac{1}{2}$  lb.; another drill, 42 in. long, with straight cutting edge  $1\frac{7}{16}$  in. wide, weight 4 lb. 10 oz.; the hammer weighs 2 lb. 14 oz.; length of head  $4\frac{1}{2}$  in., and that of handle  $7\frac{3}{4}$  in. A single-hand stone set includes shorter drill, 22 in. long, cutting edge strongly curved, and  $1\frac{1}{2}$  in. wide, and weight 3 lb. 10 oz.; longer drill, 36 in. long, cutting edge  $1\frac{7}{16}$  in. wide, and curved as in the shorter drill, and weight 6 lb. 5 oz.; hammer weighs 3 lb. 6 oz.; length of head 5 in., and that of handle 10 in. A double-hand stone set comprises first or shortest drill, 18 in. long,  $1\frac{3}{4}$  in. wide on the cutting edge, and weighs  $4\frac{1}{2}$  lb.; second drill, 27 in. long,  $1\frac{11}{16}$  in. wide on the cutting edge, and weighs 6 lb.; third, or longest drill, 40 in. long,  $1\frac{5}{8}$  in. wide on the cutting edge, and weighs  $9\frac{1}{2}$  lb.; the cutting edges of all these drills are strongly curved. Sledge weighs about 5 lb.

## DRILLING.

*Churn-drilling.*—A churn-driller will drill, in ordinary hard rock, 8–12 ft. 2-in. holes of 2·5 ft. depth per day, and at a cost of 6–9*d.* per ft., on a basis of ordinary labour at 4*s.* per day, drillers receiving 10*s.*

One man can bore, with a bit 1 in. diameter, 50–100 in. per day of 10 hours in granite, or 300–400 in. per day in limestone.

*Tamping.*—Two strikers and a holder can bore, with a bit 2 in. diameter, 10 ft. a day in rock of medium hardness.

Composition for waterproof charger or fuse consists by weight of pitch 8 parts, beeswax and tallow each 1 part. (Haswell.)

DRILLING: *Percussive and Rotary compared.*

In Table 64 is a statement of the work done each week in a three months' trial at North Skelton mines of percussive and rotary drills, to compare the capabilities of the two systems.

The work done by the percussive drill is represented by the *smaller* figures, and the work done by the rotary drill by the *larger* ones. When the trial commenced, the men working the rotary drill were strange to the mode of working the North Skelton stone, and did not therefore get on at all well for the first few weeks.

The yield for a set of 15 or 16 holes, put in in a wide place, varies from 22 to 34 wagons of stone. The yield for the same number of holes in a narrow place varies from 13 to 26 wagons of stone. Each wagon carries 30 cwt.; and if the figures showing the percentage of wide and narrow places drilled by each machine are noted, it will be seen that a greater percentage of narrow places have been drilled by the rotary drill than by the percussive, which (as compared with working the larger quantity from wide places) reduces the yield of stone per hole, and increases the cost of powder per ton.

If the results obtained during the first four weeks of the trial are carefully compared with those obtained during the last four weeks, the figures will, in these respects, speak for themselves. Turning to the cost of repairs during this trial, the percussive drill cost over 6*l.*, whilst the rotary was under 5*s.*; in fact, the difference between the value of the wiping hay used for cleaning the holes out in the case of the percussive and that needed by the rotary, would more than cover all the repairs required by the latter. There is a wide difference to the men between the working of these two classes of drills. In the percussive class, there is twice as much hard work required from the men as in the rotary, and in

Table 66.

Week ending.	Number of Places Drilled.	Percentage of Wide Places.	Percentage of Narrow Places.	Number of Holes Drilled.	Number of ft. and in. Drilled.	Stone got.	Shifts Worked this Week.	Average Number of Holes Drilled per Shift.	Average Length of Holes.	Average Stone got per Hole.	Average ft. and in. Drilled per Shift.	Excess in Quantity obtained over Percussive Drill.	Excess in Number of Holes Drilled over Percussive Drill.	Excess in ft. and in. Drilled over Percussive Drill.
1882.					ft.	in.	tons cwt.	8 hrs.	6 hrs.	ft.	in.	tons cwt.	ft.	in.
Nov. 11	18	67.23	27.77	263	1032	8	417	17	5	1	43.8	19.00	..	..
"	23	39.13	60.87	321	1245	8	409	13	5	1	53.5	15.88	..	58
Nov. 18	27	40.73	59.27	344	1385	..	..	..	..	..	40.6	12.33	..	..
"	27	40.73	59.27	344	1385	1	642	0	5	1	40.6	12.33	..	..
Nov. 25	16	50.25	43.75	239	958	9	535	12	4	1	47.8	19.21	..	..
"	25	40.00	60.00	307	1239	8	624	12	4	1	61.40	12.00	89	0
Dec. 2	17	75.00	25.00	246	968	7	497	5	4	1	49.00	12.33	..	..
"	21	50.00	50.00	342	1333	7	624	18	4	1	68.40	12.76	127	13
Dec. 9	16	61.00	39.00	251	983	9	580	14	4	1	50.20	25.87	..	..
"	24	52.00	48.00	369	1488	9	729	6	4	1	73.80	10.09	148	12
Dec. 16	17	49.00	51.00	264	1014	3	566	15	4	1	52.80	11.66	241	11
"	25	53.00	47.00	372	1498	2	808	6	4	1	74.40	11.66	241	11
Dec. 23	21	66.00	34.00	303	1174	6	797	9	5	1	50.50	25.83	..	..
"	19	39.60	60.40	467	1887	6	1066	4	5	1	57.50	10.26	268	15
D. C. 30.	17	75.00	25.00	255	1003	5	583	6	4	1	51.00	25.56	..	..
"	23	59.00	41.00	353	1450	1	883	1	4	1	70.60	15.90	299	15
1883.														
Jan. 6	17	77.50	22.50	280	1089	4	678	7	5	1	46.66	13.40	..	..
"	23	47.00	53.00	390	1576	3	835	11	4	1	78.00	13.40	157	4
Jan. 13	20	86.00	14.00	332	1311	4	772	1	5	1	56.33	18.83	..	110
"	29	51.00	49.00	522	2110	6	1116	11	5	1	87.00	13.04	344	10
Jan. 20	20	70.00	30.00	299	1175	5	703	18	5	1	79.51	21.36	..	190
"	30	52.00	48.00	501	2051	7	1049	13	5	1	61.34	14.03	345	15
Jan. 27	20	60.00	40.00	313	1220	10	802	10	5	1	52.18	22.22	..	202
"	30	53.00	47.00	518	2136	1	1186	0	5	1	86.30	12.80	383	10

*Percussive and Rotary—continued.*

point of comfort there is no comparison, the machinery in the rotary case doing all the work, and the men are kept quite dry; but in attending to the percussive, they are working very wet during the whole shift, and have to do much more laborious work in the fixing of the drill in each place, as well as during its general working. The water needed for drilling with the percussive drills has to be led out of the places going to the dip, and in all the places the state of the roads is made very disagreeable and objectionable for the men and horses travelling upon them. In the use of the percussive drills, a second costly main of pipes, with all necessary connections and cocks for conveying the water under a heavy pressure into every place, has to be provided and kept in order, involving double cost in both pipes and skilled labour.

Since the date of this competitive trial, further improvements have been added to the rotary drill, by which a 4-ft. hole can be put in with 1000 revolutions less of the engines, and the holes cleaned of the small drillings, thus saving a considerable amount of skilled labour, reducing the consumption of the compressed air and the wear and tear on the drilling machine by 71 per cent.

Both the machines here referred to have been continued at work at North Skelton every day, and (working two shifts) the rotary is now daily averaging 324 tons of stone, whilst the quantity from the percussive is not much more than one-third of this.

At the St. Andreasberg silver mines in the Harz, rock drills worked by compressed air have recently been introduced. The air compressor is placed underground, and is driven by a Girard turbine. The special point of interest in connection with this installation is the regulator, which consists of an air reservoir hewn in the solid rock. By the employment of power drills, it is found that in driving levels there is a saving in cost of 58 2 per cent., whilst 4.04 times as much work is done as that accomplished by manual labour. The cost of stoping by hand was 16s. as compared with 8s. 6d. by machine per cub. metre of ore won. In the case of shaft sinking, the cost with machine, inclusive of explosives, was 4l. per running metre, as compared with 7l. 10s. with manual labour.

*Electric Mining Drills.*

The transmission of power by electricity offers special advantages in the case of movable machines such as drills. This is mainly due to the fact that the power is conveyed by means of small, flexible, stationary wires or cables, which are capable of almost infinite extension, which may be buried underground, hung on the sides or roof, coiled on a drum, built at any angle, or moved from place to place, without in any way interfering with the working of the machinery; nor are the machines themselves less easily managed than the cables which transmit the power to them.

Probably no firm has done more to render electric mining

*Electric Drills—continued.*

machinery a practical working success than W. T. Goolden and Co., of London, and the following examples are therefore chosen from among their many mining machines to show the advances made in this direction. Goolden's drilling machines are of three classes:

- (1) Rotary borers for coal or comparatively soft shale or stone.
- (2) Light percussion drills for small holes in soft material.
- (3) Powerful percussion drills for larger holes in hard rocks.

Class (1) is suitable for drilling shot-holes in coal and similar material, and in fact is to replace the hand-borers now frequently used. In this machine the small electric motor is mounted on the base of the machine which forms the trolley on which it is moved from place to place. It is of the usual "Goolden" mining type, all parts being completely inclosed in dirt-, damp-, and gas-tight cases, so that it can be used if required in presence of explosive mixtures of gases, without any fear of a spark causing an explosion. This motor drives a vertical shaft, which in turn drives the drill. The vertical shaft has a feather-way cut in it throughout its length, so that the drill motion can be raised or lowered and fixed at any desired height on a tubular column provided for this purpose. By means of a simple arrangement of the gearing, the drill may be set to bore in any direction, that is at any inclination either to the horizontal or vertical planes, so that it may be said to be perfectly universal. It is further fitted with a variable feed motion, so that by the adjustment of a screw the rate of feed may be varied while the machine is working to any desired extent, thus allowing the machine to be worked all the time at its full power without fear of straining any part. The whole of the gearing is completely inclosed in dirt-tight cases to protect it from wear or damage from falling stone or *debris*, and in every way the machine is designed to meet the rough usage of ordinary mining practice. In using the machine, it may be either lifted from its carriage and allowed to stand on the base of the column, being clamped against the roof or timbers by means of a screw at the top of the column, or it may be left on the trolley and simply clamped in position as it stands, according to circumstances. The cable for use with this machine is a small "twin" or "concentric," one which may be rolled on a drum or coil or simply pulled after the machine as it is moved from place to place.

Class (2) is a small 1 to 2 H.P. percussion drill giving 100 to 200 blows per minute, and suitable for drilling holes up to 1 in. diam. in moderately hard stone. In this machine, for ease of transport, the motor and drill are made quite separate. The motor is an ordinary "Goolden" mining motor, and is mounted on a small trolley so that it can be easily moved, and is quite complete in itself, with all the necessary appliances for starting and stopping. The drill is also distinct, and much resembles some of the well

*Electric Drills—continued.*

known hand-power percussion drills; it is light but strong, portable but substantial, and well calculated to stand rough handling by inexperienced men. It is provided with an efficient automatic feed motion, so that it follows its work with little attention, and is readily set to drill in any direction or at any height. The power is conveyed from the motor to the drill, first through a pair of strong spur gear, in which the pinion is made of a composition of vulcanised fibre and iron, to make it run silently, and then by means of a length of flexible shafting to the drill. By this means the drill may, within wide limits, be set at any distance from or at any angle to the motor, without in any way interfering with the working of the machinery.

Class (3) is a large 5-10 H.P. reciprocating drill for drilling holes up to  $2\frac{1}{2}$  in. diam. in the hardest rocks, and is capable of giving 600-1000 blows per minute. This drill consists of a strong iron cylinder, resembling the cylinder of an air drill, in which are inclosed all the electrical and reciprocating parts. This cylinder is mounted on the usual sliding carriage fitted with a screw feed-motion. The drill is essentially simple in construction, and as it contains no moving electrical parts or connections, is entirely free from the objections sometimes met with in this class of machinery arising from the delicate nature of these contacts. In fact as the only moving part consists of the piston and piston-rod, and as there is no valve gear, there is less to get out of order than in the ordinary steam drill, while on account of the greater number of blows obtainable, more work can be done with this drill than with any other form of machine. The drill is mounted on a variety of forms of carriages or pillars to suit different classes of work, and is eminently suited for all classes of quarrying and mining use, while at the same time, on account of the small size of concentric cable required for transmitting power to it, it can be very readily moved from part to part of a mine as required.

*Rock Drilling Plants.*

The following information concerning the well-known patent Adelaide Rock-drills, has been obligingly contributed by the sole manufacturers, Commans & Co., 52, Gracechurch Street, London, E.C.

Table 67.—*Cost of Drills.*

Size	$2\frac{1}{2}$ in.	3 in.	$3\frac{1}{2}$ in.	$3\frac{3}{4}$ in.	4 in. diam. of cylinder.
Price	36l.	40l.	44l.	47l.	56l.





*Useful Notes*—continued.

given above, as often, owing to loss due to clearance, heat and leakage, the actual amount of air discharged from an ordinary compressor with poppet valves is 25 per cent. less than the theoretical amount.

Safe figures are:—

Size of Drill	2½ in.	3 in.	3½ in.	3¾ in.	4 in.
Cubic ft.	10	15	17	20	25

With the best compressors, the loss of efficiency ought not to be more than 10 per cent. It is false economy to employ too small a compressor. Where a number of drills have to be driven, an allowance might be made, which could not be done in the case of a compressor to drive only two machines.

An effective air pressure of 50-75 lb. per sq. in. is usually employed for working drills. The lower pressures are used for drills employed on soft rock, and for machines which do not work expansively, using the full air pressure throughout the stroke. There is no economy in working with air at too low a pressure. The only limit to the pressure is the point when the tool gets too quickly blunted; the cost of the men to run the drill is a considerably greater item than that of compressing the air.

The air should be drawn from outside the engine room, and from as cool a place as possible.

When air is compressed to more than one or two atmospheres, the temperature rises rapidly, necessitating the cylinder being water jacketed. Injection of water into the cylinder, although it cools the air more rapidly, is not to be recommended, as it soon rusts the walls of the cylinder, permits only of a slow speed of piston, and produces moist air, which often causes a freezing-up of the exhaust ports of the drills. The cooling not only effects a saving in power required for compressing, but prevents decomposition of the oil, and permits proper lubrication by keeping the cylinder and glands cool. The piston speed of ordinary compressors usually varies from 250 ft. to 400 ft. per minute, according to the size of the compressor.

A good fly wheel should be employed, more especially in direct acting compressors, to ensure steady running, and to equalise the difference between the steam pressure and air resistance.

*Rule.*—Assuming the temperature to remain constant, and that compression is carried on isothermally, the absolute pressures (the total pressures above a vacuum) at any two points of the stroke are, according to Boyle's or Marriotte's Law, inversely proportional to the volumes at these points, so that if

$P$  = the original pressure.

$P^1$  = „ new „

$V$  = „ original volume.

$V^1$  = „ new „

$P^1 : P = V : V^1$ .

*Useful Notes—continued.*

*Ex. 1.*—What vol.  $V^1$  will 100 cub. ft. of atmospheric air (which at the sea level averages about 15 lb. per sq. in.) occupy, when compressed to 60 lb. or 4 atmospheres effective pressure (5 atmospheres absolute)?

$$\begin{aligned} V^1 &= \frac{P \times V}{P^1} \\ &= \frac{15 \times 100}{60 + 15} = 20 \text{ cub. ft.,} \end{aligned}$$

or  $\frac{1}{5}$  of the original volume. So that approximately the volume of compressed air is equal to the original volume divided by the number of atmospheres (absolute) to which it has been compressed.

*Ex. 2.*—Required the size of compressor to supply air at 60 lb. effective pressure to work two 3-in. drills.

Air required per minute:—

$15 \times 2 = 30$  cub. ft. at 60 lb.,  
or,  $30 \times 5 = 150$  „ of free air at atmospheric pressure would be required per minute to work both drills simultaneously.

Taking the piston speed at 300 ft. per minute:—

$$\begin{aligned} \text{Area of cylinder} \times 300 &= 150 \\ \text{„ „} &= \frac{150}{300} = 72 \text{ sq. in.,} \end{aligned}$$

which represents a cylinder diameter of  $9\frac{3}{4}$  in., to which the nearest sized compressor would be 10 in. diameter.

A smaller plant than a 10-in. compressor and two drills is very seldom employed, and would not be economical.

*Ex. 3.*—Required the size of compressor to supply air at 60 lb. effective pressure to work six  $3\frac{1}{2}$ -in. drills.

Air required per minute:—

$20 \times 6 = 120$  cub. ft. at 60 lb. pressure,  
or,  $120 \times 5 = 600$  „ of free air at atmospheric pressure.

Assuming a piston speed of 350 ft. per minute:—

$$\begin{aligned} \text{Area of cylinder} \times 350 &= 600 \\ \text{„ „} &= \frac{600}{350} \text{ sq. ft.} = 247 \text{ sq. in.,} \end{aligned}$$

which represents a cylinder of  $17\frac{3}{4}$  in. diameter, the nearest sized compressor to which would be an 18-in. It would be possible to drive the 6 drills with a 16-in. compressor running a little faster, and taking into consideration that seldom more than 5 drills would

*Useful Notes*—continued.

be working at one time; on the other hand it would be more economical, and better in the long run, to employ an 18-in. compressor.

*Compressors for Mountainous Districts.*—As the density of the atmosphere decreases with the height above the sea level, allowance must be made for this when calculating a compressor plant to work at a high altitude. Taking the efficiency at the sea-level to be 100, the decrease in efficiency is approximately 3 per cent. for every 1000 ft. above the sea level.

*Air Receivers.*—These are inserted between the compressing engine and the machines to be driven, in order to keep as far as possible a steady working pressure, and allow the air to flow through the mains with a uniform velocity.

If the air has to be carried a very long distance, it is advantageous to employ two receivers, one close to the compressor, the other near the point where the power is being taken off. By this means a steady flow of air through the pipes is secured, and the friction is thereby considerably reduced.

No hard and fast rule can be given for the size of receivers; the larger they are within reason the better. For a single cylinder compressor the receiver should, for example, be larger than for a compressor of 2 or more cylinders. An allowance of not less than 10 cub. ft. per drill should be made. It will suffice if the volume of the receiver has a capacity of about double the volume of air discharged from the compressor.

*Air Mains.*—Care should be taken when designing a plant to make the mains of ample size, so as not to throttle the air, and where possible to avoid angles and bends.

Wrought or cast iron flanged pipes are best for carrying the air into the mine; ordinary steam piping can be used for the distribution of the air underground.

The loss of pressure is proportional to the length of the pipe and the square of the velocity.

A fair velocity to assume is 25-30 ft. per second, so that for example the size of main for an 18-in. compressor delivering some 120 cub. ft. per minute would be:—

$$\frac{120}{60 \times 30} \times 144 = 9.6 \text{ sq. in.,}$$

or a diameter of pipe about  $3\frac{1}{2}$  in.

*N.B.*—Further information will be found on p. 378.

Table 69.—Air Compressors.

Diameter of air cylinder..	10 in.	12 in.	14 in.	16 in.	18 in.	20 in.
Piston speed 300 ft. per minute.						
Theoretical volume of air entering cylinder, in cub. ft. per min. . . .	165	235	321	420	531	655
Actual volume taken, 25% less, in cub. ft. . . .	124	177	241	315	399	492
Volume of air delivered at 60 lb., in cub. ft. . . .	21·8	35·4	48·2	63·0	79·8	98·4
Volume of air delivered at 70 lb., in cub. ft. . . .	21·8	31·2	42·5	55·5	70·4	86·8
Piston speed 350 ft. per minute.						
Theoretical volume of air entering cylinder, in cub. ft. per min. . . .	192	273	372	487	616	764
Actual volume taken, 25% less, in cub. ft. . . .	144	205	279	366	462	573
Volume of air delivered at 60 lb., in cub. ft. . . .	28·8	41·0	55·8	73·2	92·4	114·6
Volume of air delivered at 70 lb., in cub. ft. . . .	25·4	36·1	49·2	61·5	81·5	101·1
Piston speed 400 ft. per minute.						
Theoretical volume of air entering cylinder, in cub. ft. per min. . . .	220	313	428	560	708	873
Actual volume taken, 25% less, in cub. ft. per min.	165	235	321	420	531	655
Volume of air delivered at 60 lb., in cub. ft. . . .	33	47	64·2	84	106·2	131
Volume of air delivered at 70 lb., in cub. ft. . . .	29·1	41·4	56·4	74·1	93·6	115·5
Number of 3-in. drills the compressor will drive..	2	4	6 to 8	8 to 10	10 to 12	14 to 16
Number of 3½ in. drills the compressor will drive ..	1 to 2	2 to 3	4 to 5	5 to 6	6 to 8	10 to 12
Nominal H.P. . . . .	8	12	18	25	30	40
Size of receiver, diameter and lengths . . . .	3 × 6 ft.	3 × 8 ft.	3½ × 8 ft.	3½ × 10 ft.	4 × 12 ft.	4½ × 15 ft.
Diameter of air main . .	2 in.	2½ in.	3 in.	3½ in.	4 in.	5 in.
Price of compressors with ordinary poppet valve, £	184	226	289	334	397	492
Price of high class compressor with patent valves . . . . £	276	340	434	500	592	738
„ receiver . . . £	20	30	35	45	55	65
„ boiler . . . £	100	125	175	220	260	350
„ donkey pump . £	15	18	20	25	25	30
„ ordinary connections . . . £	10	12	15	20	20	25

## BLASTING.

In blasting, rock requires from  $\cdot 25$ - $1\cdot 5$  lb. gunpowder per cub. yd., according to its degree of hardness and position. In small blasts 2 cub. yd. have been rent and loosened, and in very large blasts 2-4 cub. yd. have been rent and loosened, by 1 lb. powder.

Tunnels and shafts require  $1\cdot 5$ -2 lb. per cub. yd. of rock.

*Gunpowder* has an explosive force varying from 40,000 to 90,000 lb. per sq. in. That used for blasting is much inferior to that used for projectiles, the proportion being fully one-third less.

*Nitro-glycerine* is an unctuous liquid, which explodes by concussion, an extreme pressure (2000 lb. per sq. in.), or a temperature exceeding  $600^{\circ}$  if quickly applied to it; it will inflame, however, and burn gradually.

At a temperature below  $40^{\circ}$  it solidifies in crystals.

Its explosion is so instantaneous that in rock-blasting tamping is not necessary; its explosive power by weight is 4-5 times that of gunpowder.

*Dynamite* is nitro-glycerine 75 parts, absorbed in 25 parts of a siliceous earth termed *kieselguhr*; it also explodes so instantaneously as to render tamping in blasting quite unnecessary.

It is insoluble in water, and may be used in wet holes; it congeals at  $40^{\circ}$ , is rendered ineffective at  $212^{\circ}$ , and has an explosive force by weight of 3 times that of gunpowder, and by bulk 4-25 times.

*Gun-cotton* is insoluble in water, and has an explosive force by weight of  $2\cdot 75$ -3 times that of gunpowder, and by bulk 2-5 times. It may be detonated in a wet state with a small quantity of dry material.

*Tonite* is nitrated gun-cotton, and is known also as cotton powder. It is produced in cartridge form.

*Litho-fracteur* is a nitro-glycerine compound in which a portion of the base or absorbent material is made explosive by the admixture therein of nitrate of baryta and charcoal.

*Cellulose Dynamite* is when gun-cotton is used as the absorbent for nitro-glycerine; it will explode frozen dynamite, and is more sensitive to percussion than it.

*To Compute Charge of Gunpowder for Rock Blasting.*

*Rule.*—Divide cube of line of least resistance by 25 as for limestone, to 32 for granite, and quotient will give charge of powder in lb. Or,

$$L^3 \div 32 = \text{lb.}$$

*Example.*—When line of least resistance is 6 ft., what is charge required?

$$6^3 \div 32 = 6\cdot 75 \text{ lb.}$$

Line of least resistance should not exceed  $\cdot 5$  depth of hole.

*Tamping.*—Dried clay is the most effective of all materials for tamping; broken brick the next, and loose sand the least.

Table 70.—*Weight of Explosive Materials in Holes of different Diameters per inch of Length.*

Diameter.	Powder or Guncotton.	Dynamite.	Diameter.	Powder or Guncotton.	Dynamite.
in.	oz.	oz.	in.	oz.	oz.
1	·419	·67	2·25	2·12	3·392
1·25	·654	1·046	2·5	2·618	4·189
1·5	·942	1·507	2·75	3·166	5·066
1·75	1·283	2·053	3	3·769	6·03
2	1·675	2·68			

Table 71.—*Boring Holes in Granite.*

Diameter of Jumper.	Depth of Hole.	Men.	Depth bored per Day.	Hammer.
in.	in.	No.	ft.	lb.
1	1 to 2	1	8	6
1·75	2·5 to 6	3	12	14
2	4 to 7	3	8	14
2·25	5 to 10	3	6	16
2·5	9 to 12	3	5	16
3	9 to 15	3	4	18

*Drill.*—Width of bit compared to stock, ·625.

### *Charges of Powder.*

Usual practice of charging to one-third depth of hole is erroneous, inasmuch as volume of charge increases as square of diameter of hole. Hence holes of 1·5 and 2 in., although of equal depths, would require charges in proportion of 2·25 and 4.

Line of Least Resistance.	Powder.	Line of Least Resistance.	Powder.
ft.	lb. oz.	ft.	lb. oz.
1	0 0·75	5	3 14·5
2	0 4	6	6 12
	0 13·5	7	10 11·5
	2 0	8	16 0

*Effects.*

*Gunpowder*, from its gradual combustion, rends and projects rather than shatters.

A hole 5.5 in. diameter and 19 ft. 7 in. deep, filled to 8 ft. 10 in. with 75 lb. powder, has removed and rent 1200 cub. yd., equal to 2400 tons. The labour expended was that of 3 men for 14 days.

Temperature of gases of explosion  $4000^{\circ}$ .

*Gun-cotton*, from the rapidity of its combustion, shatters.

*Dynamite*, from the greater rapidity of its combustion over gun-cotton, is more shattering in its explosion.

In small blasts 1 lb. powder will loosen about  $4\frac{1}{2}$  tons. In large blasts 1 lb. powder will loosen about  $2\frac{3}{4}$  tons.

One man can bore 50–100 in. per day in granite, or 300 to 400 in. per day in limestone.

In small charges of dynamite, weak caps seem to develop the full strength of the explosive; but in large charges stronger caps are necessary. Gun cotton and gelatine dynamite require much stronger caps than those ordinarily used for dynamite. Gun cotton seems to produce a more rending explosion than dynamite. The statement made on good authority that black powder fired with a detonator is much more powerful than when fired by fuse alone, has been disproved.

*Explosives and Firedamp.*

The possibility of firing firedamp by the flame of a shot depends on the greater or less intensity of the flame. This intensity depends especially on the time which is necessary to produce the complete combustion (vaporisation) of the explosive. Inversely to the force of the explosive, this intensity increases with the length of time required for the explosive particles to become incandescent at the time of their decomposition and to form combustible gases.

Gunpowder burns slowly, and it is a well-known fact that particles of powder still in combustion or still unignited, may be projected for a long way by the flame jet. According to Trauzl, the rapidity of combustion of a grain of gunpowder is never greater than 10 mm. per second, and the rapidity with which the flame is propagated from particle to particle not more than 10 m. per second. A cartridge 1 ft. in length would therefore require  $\frac{3}{10}$  second in order to be in full combustion, whilst the different particles, admitting they were only 1 mm. in diameter, would require  $\frac{1}{10}$  second in order to burn completely. But on account of the violent pressure of the explosive gases, especially when the charge is too strong or the tamping defective, it is possible at the end of  $\frac{1}{10}$  second to have several jets of flame several yd. in length, which are often sufficient to inflame the firedamp which may be within their reach. In proportion as the powder is coarse, and burns slowly, is it more dangerous. The use of compressed powder recommended by the

*Explosives—continued.*

French Commission is not satisfactory, and Trauzl admits rightly that in the presence of firedamp this powder is highly dangerous. The statement of gunpowder manufacturers that the danger of gunpowder, both ordinary and compressed, would be eliminated if the charge were fired by strong capsules, such as are used for dynamite, was by no means verified in the Neunkirchen experiments.

Other explosives of great rending force, such as dynamite, gun-cotton, &c., act altogether differently. According to Trauzl long charges of compressed guncotton or dynamite fired at one extremity by means of strong capsules, detonate even in a free state, at the enormous rapidity of 5000–6000 m. per second, and a dynamite cartridge 1 ft. in length explodes in  $\frac{1}{5000}$  second. Owing to this marvellous rapidity of propagation, and which also accounts, as is well known, for the violent effects of these explosives, the possibility of inflaming the firedamp, if not completely excluded, is, at least, undoubtedly limited. The incandescence of the decomposed explosive particles is of such short duration, especially when the tamping and capsules are good and efficient, that the flame hardly passes beyond the mouth of the borehole. It is not only the results of the Neunkirchen experiments which confirm the difference in the rapidity of action between gunpowder and other explosives such as those mentioned above; but the practical experiments of the English Commission on Accidents in Mines, and the Saxon Commission, also yielded precisely similar results. We gather from all these experiments that, though the danger of firing firedamp and coal dust through the use of gunpowder for blasting purposes is very great, yet the danger is greatly reduced, if not altogether averted, by the use of other explosives of a more rapid action, provided that there are not exceptional accumulations of gas.

Under these circumstances the Prussian Commission considers that, from the point of view of security, the use of gunpowder should be absolutely interdicted in fiery mines, and that the use of other explosives should be tolerated, provided that the proportion of firedamp does not pass beyond a dangerous limit easy to recognise. It enjoins as follows:—"That the use of gunpowder and other slow explosives should be forbidden in fiery mines, and the use of dynamite and other explosives which act in the same way as dynamite in the presence of coal dust should be authorised only. The use of dynamite should be equally forbidden in those portions of a mine where, under ordinary circumstances, accumulations of firedamp cannot be avoided, nor their presence easily indicated by the aid of the safety lamp."

Amongst explosives of a rapid action, those of a nitro-glycerine character are the best known and most used in coal working. Such are dynamite, No. 1 kieselguhr, and dynamite cellulose, dynamite Nobel, Nos. 2, 3, and 4, dualine, explosive gelatine, gelatine dynamite. Also nitro-cellulose (gun-cotton, &c.), Schultze's



*Explosives—continued.*

powder, kinetite, and others, such as hellhoffite (explosive Sprengel) carbonite, anagone, securité, and roburite, &c. According to the Neunkirchen experiments dynamite-guhr appears to be the least secure against inflammation of firedamp and coal dusts, because it was found that the mixture could be fired with only  $4\frac{1}{2}$  per cent. of gas. On account of the mixture of nitro-glycerine with the inert kieselguhr, the rapidity of propagation of the flame in the dynamite cartridge is diminished, and particles of this projected by the violence of the explosion, and in a state of incandescence, increase the action of the flame. It is easy to conceive that in the driving of a cross-cut yielding a good deal of gas, the gas must be ignited by the flame of the dynamite. This has frequently been observed in the Obernkirchen mines, and the Westphalia Mine, near Dortmund. The mixture of combustible powder with dynamite appears to exert an influence on the safety of the latter, but this influence is only felt in the presence of a large proportion of powder. Thus, whilst unmixed explosives, such as gunpowder, explosive gelatine, hellhoffite, &c., as well as kinetite and dynamite-gelatine No. 1—which only contains 35 per cent. of powder—proved themselves absolutely without danger, in the Neunkirchen experiments, even in the presence of 10 per cent. of firedamp and coaldust, dynamite-gelatine No. 3 (75 per cent. of mixed powder) produced inflammation in the presence of 6 per cent. of firedamp. The Administration of Mines of Saxony obtained similar results with dynamite-guhr and dynamite-gelatine at the time of its experiments at Brückenberg, Shaft No. 1, near Zwickau, in the summer of 1885. Some new experiments under the direction of the Royal Inspection of Mines at Neunkirchen were productive of remarkable results, illustrative of the action of explosives invented of late years. Schultze's powder, of great exploding power, was found to be harmless in the presence of firedamp and coaldust, whilst other qualities of the same powder, such as the explosive known as anagone, were not so secure. The explosive known under the name of securité also appeared to be of a harmless description in the presence of firedamp and coaldust, but, like Schultze's powder, it is hygroscopic, and cannot be used in a moist state. Carbonite, manufactured by Schmidt and Bichel, Berlin, appeared to yield satisfactory results from every point of view, and it seems likely that this explosive will be used instead of gunpowder in fiery mines, chiefly because it is able to contend advantageously with it as regards net cost.



## PUMPING.

*Horse-power required to Pump 1 gal. of Water against Various Pressures, allowing 40 per cent. for friction.*

Pressure per sq. in.		Calculated with 40 per cent. added.			Horse-power required.
700	..	0.68	..	..	say .75
1,500	..	1.47	..	..	„ 1.75
2,240	..	2.19	..	..	„ 2.5

*Useful Numbers for Pumps.*

D = Diameter of pump (in.).

S = Stroke of pump (in.).

$D^2 S \times .7854 = \text{cub. in.}$

$D^2 S \times .002833 = \text{gal.}$

$D^2 S \times .0004545 = \text{cub. ft.}$

$D^2 S \times .02833 = \text{lb. fresh water.}$

*To find Diameter of Single-acting Pump.*

L = Length of stroke in ft.

G = Number of gal. to be delivered per minute.

F = Number of cub. ft. to be delivered per minute.

N = Number of strokes per minute.

D = Diameter of pump (in.).

$F = .00545 D^2 L N.$

$G = .034 D^2 L N.$

$$D = \sqrt{\frac{G}{.034 L N}}$$

$$D = \sqrt{\frac{F}{.00545 L N}}$$

*Note.*—These formulæ give the net diameter of the pump-plunger; it is usual to increase the area of the plunger  $\frac{1}{4}$ , to allow for leakage, &c.

*Setting up and Running Steam Pumps.*

Never use a smaller pipe on the suction than the list indicates.

Avoid right angles in the pipe where it is possible.

Where it is practicable, make bends with a large radius.

Put a foot valve and strainer on the end of the suction pipe.

Do not place the pump more than 29 ft. from the water.

Where hot water is pumped, the supply must be above the pump.

*Steam Pumps—continued.*

Make all joints in the suction pipe tight.

A small leak in the suction is very detrimental.

Keep the stuffing boxes nicely packed.

Oil the pump before starting it, and keep the oil wiped off where it is not needed.

A good pump is as worthy of being taken care of as a good engine; spend a few moments every day in cleaning them up, removing all extra oil from them, wiping off the dust and dirt, and see that they are in good condition and working well.

*Pumping Engines.*

G = Number of gal. to be raised in 24 hours.

F = Number of cub. ft. raised in 24 hours.

h = Height in ft. to which the water is to be raised.

H P = Actual horse-power required.

$$H P = \frac{G \times h}{4752000} \text{ or } \frac{F \times h}{762088}.$$

20 per cent. must be added to overcome friction, &c., and 50 or 60 per cent. more is usually allowed for contingencies, making a total of 70 or 80 per cent. additional power.

*To find Horse-power of Pumping Engines.*

Let G = the number of gal. required per hour; C = the number of cub. ft. required per hour; F = the height in ft. to which the water is to be raised = horse-power.

$$\text{Then} = \frac{G \times F}{198,000} \text{ or } = \frac{C \times F}{31,750}.$$

About 70 or 80 per cent. must be added to the number obtained by the above formula, to allow for frictional and other contingencies; the result obtained by the formula is not in nominal but in actual horse-power (33,000 foot-pounds).

Table 73.—Power required to Raise Water from Deep Wells.

Gal. of water raised per hour ..	200, 350, 500, 650, 800, 1,000
Height of lift for one man working on crank in ft. .. }	90, 52, 36, 28, 22, 18
Height of lift for one donkey working on gin in ft. .. }	180, 102, 72, 56, 45, 36
Height of lift for one horse working on gin in ft. ... }	630, 357, 252, 196, 154, 126
Height of lift for one horse-power steam engine in ft. .. }	990, 561, 396, 308, 242, 198

This table is based on the assumption that a good class of treble or double-barrel lift pump is used, with valves in the buckets, with an additional retaining valve for lifts above 100 ft.

*To find Pressure per sq. in. of a Column of Water (Telford).—*Multiply the height in ft. by  $\cdot 434$ . The pressure per circular in. may be found by multiplying the height in ft. by  $\cdot 341$ . *Ex.*—Required the pressure in lb. per sq. in. of a column of water 200 ft. high.

$$200 \times \cdot 434 = 86\cdot 8 \text{ lb. per sq. in.}$$

A ready way of approximately ascertaining the pressure is to take half the height in ft.

*To find Pressure of a Column of Water in lb.*—If the base be circular, square the diameter in inches, and multiply by  $\cdot 341$ , which gives the weight of 1 ft. in height; by multiplying by the number of ft. in height, the pressure is found. If the base be square, multiply by  $\cdot 434$ . *Ex.*—Required the pressure of a column of water 12 in. diameter and 20 ft. high.

$$12 \times 12 \times \cdot 341 \times 20 = 982\cdot 080 \text{ lb. if the base be circular.}$$

$$12 \times 12 \times \cdot 434 \times 20 = 1\cdot 249\cdot 920 \text{ lb. if the base be square.}$$

*To find Quantity of Water in a Pipe.*—The square of the diam. in inches gives the weight of water in lb. for 3 ft. in length, and by striking off one figure to the right the number of gal. is found. *Ex.*—Required the quantity of water which a pipe 15 in. diameter and 9 ft. long will contain :—

$$15 \times 15 \times 3 = 675 \text{ lb., or } 67\cdot 5 \text{ gal.}$$

*To find Diameter of Pipe required to Discharge a Given Quantity of Water at a Given Speed per Minute.*—**RULE:** Multiply the

number of cub. ft. of water per minute by 144, and divide by the velocity of flow in ft. per minute; divide by  $\cdot 7854$ , and take out square root, which will give diameter of pipe.

*To find Velocity of Flow of Water in a Pipe required to Discharge a Given Volume of Water in a Given Time.*—**RULE:** Multiply the number of cub. ft. of water by 144, and divide the product by the area of the pipe in inches.

### *Centrifugal Pumps.*

Centrifugal pumps and direct acting pumping engines are largely employed in the mining industry, and as their usefulness becomes better known their employment will be extended. On moderate lifts, such as those prevailing in alluvial mines, no better water elevator can be adopted (1) on account of their great efficiency; (2) because, in the absence of valves, they will pass mud, grit, chips, &c., without detriment to their working; (3) by reason of their very low first cost and trifling cost of repairs. The "Invincible" pumping engine, made by John and Henry Gwynne, of Hammer-smith Ironworks, and Cannon Street, London, is claimed to be, on certain lifts, more economical than any pump of the centrifugal or other type, or than scoop wheels, or any other water-raising appliance known.

### *Pulsometers.*

The distinguishing features of the pulsometer are briefly as follow:—The pump itself is not subject to wear like other pumps. The only wearing parts (the valves) can be readily and cheaply renewed. Such renewals are needed only at long intervals. No expense for skilled labour. Whilst on constant work the pulsometer will run for long periods unseen. It requires no oil, tallow, packings, or foundations. Will work equally well suspended on a chain as when fixed, and can be used whilst being lowered. For sinking work the great advantage of this capability will be readily recognised. The pulsometer will go into a smaller space than any other pump of equal capacity. Having no exhaust steam, it can be used in confined spaces without heading them up, as is the case with ordinary steam pumps. The pump is noiseless in operation. They will pump very dirty water and a great variety of other liquids and semi-liquids to a total height of 70–80 ft., or under special circumstances to much greater heights. They are best adapted to a suction not exceeding 6–10 ft. for the smaller size, and 10–15 ft. for the larger. These figures are, of course, modified by circumstances, as pulsometers are occasionally used on very much higher lifts, but the above may be safely taken as a guide. As a convenient guide also it may be stated that the pressure of steam at the pump for lifts of 20–40 ft. should not be less than 20–30 lb. per sq. in., and for lifts of 40–80 ft. not less than 30–50 lb. For

*Pulsometers—continued.*

higher lifts greater steam pressure is necessary. The pulsometer can be made in gunmetal, to withstand the action of bad water sometimes met with in mines. The advantages enumerated as belonging specially to the pulsometer in its portability, its ability to raise very dirty water, &c., without injury, its small size, cost, and general handiness, have already established its reputation for all kinds of pumping in mines, &c. If desired, for lifts above 90–100 ft., the discharge of one pulsometer may be taken into the suction of another pulsometer placed above; or a small tank may be placed midway, the bottom pump discharging into it and the higher one drawing from it. Either of these arrangements is used with great success, and in this way a large number of very awkward sinking jobs have been performed. For lifts above the range of the pulsometer, the “Deane” Patent Double-Plunger Sinking Pump is strongly recommended. It will pump gritty water to almost any height; is strong and very simple. It can also be made in small parts for easy transit in mountainous countries.

Table 74.—*Pulsometers.*

No.	Height of Pulsometer.	Space occupied.	Size of Steam Supply Pipe.	Size of Suction Pipe.	Size of Discharge Pipe.	Imperial Gallons per Hour.
	in.	in.	in.	in.	in.	
1	18	10 × 10	$\frac{1}{4}$	$1\frac{1}{8}$	1	900
2	22	15 × 13	$\frac{1}{2}$	2	$1\frac{1}{2}$	2,000
3	28	23 × 15	$\frac{3}{8}$	3	2	3,800
4	32	24 × 20	$\frac{1}{2}$	$3\frac{1}{2}$	$2\frac{1}{2}$	6,000
5	39	25 × 25	$\frac{3}{4}$	4	3	10,000
6	42	27 × 27	1	$4\frac{1}{2}$	$3\frac{1}{2}$	13,000
7	48	32 × 26	$1\frac{1}{4}$	5	4	17,000
$7\frac{1}{2}$	51	39 × 28	$1\frac{1}{2}$	5	4	22,000
8	56	39 × 32	$1\frac{1}{2}$	6	5	28,000
9	66	39 × 36	$1\frac{1}{2}$	7	6	40,000
10	79	48 × 42	2	8	7	52,000
$11\frac{1}{2}$	80	56 × 42	2	10	8	80,000

The quantities are given on a total lift of about 20 ft.

VENTILATING.

Table 75.—VENTILATING: *Efficiëncies of Mechanical Ventilators.* (N. Eng. Inst. Min. Engs.)

No.	Name of Ventilator.	Dimensions of Ventilator.				Dimensions of Engines.				General Results.			
		Diameter.	Width, &c.	Theoretical Displacement per Minute.	Diameter of Inlet.	Weight.	No. of Cyls.	Plam. of Cylinders.	Length of Stroke.	Direct-acting or Geared.	Volume of Air per Minute.	Mean Water Gauge at Inlet Door.	Percentage of Useful Effect.
		ft. in.	ft. in.	cub. ft.	ft. in.	tons		in.	ft. in.		cub. ft.	in.	
1	Guibal ..	Fan .. 50 0	.. 12 0	..	16 0	50	1	42	3 6	Direct.	108,422	3-30	40-00
2	" ..	" .. 46 0	.. 14 10	..	13 0	..	1	36	3 6	"	246,509	1-85	52-95
3	" ..	" .. 40 0	.. 12 0	..	14 0	24	1	36	3 0	"	170,581	1-46	47-95
4	Waddle..	" .. 45 0	{ Inlet .. 6 6 Periphery 1 5	..	15 0	..	1	32	4 0	"	163,312	3-08	52-79
5	Schiele ..	" .. 12 0	{ Inlet .. 3 2 Periphery 1 8	..	..	..	1	25	2 0	2-57 to 1	157,176	1-91	46-12
6	" ..	" .. 9 6	{ Inlet .. 3 2 Periphery 1 8	..	8 0	..	1	20	1 8	24 to 1	106,570	2-03	49-27
7	Lemelle	{ Chamber 22 6 Drum .. 15 0 2 pistons 18 3	{ Height 32 0 Stroke 7 0	9-9 rev. 103,900 6-50 " 47,827	..	..	1	55	6 0	Direct	47,307	1-37	23-40
8	Struvé ..	{ 2 pistons— Long.. 30 0 High.. 50 0	{ Stroke 7 3	7-19 " 120,790	..	..	1	24	4 4	4 to 1	43,793	5-11	57-80
9	Nixon ..	{ 2 drums 25 0 2 drums 15 0 Casing .. 22 0 2 pistons 13 2	{ Stroke 10 7 1/2	9-25 " 53,020	..	..	1	36	6 0	Direct	72,595	2-74	45-91
10	Root ..		.. 13 0	16-71 " 96,918	..	..	2	28	4 0	"	89,772	3-29	47-84
11	Cooke ..		.. 11 6	17-92 " 80,640	..	..	1	25	3 6	"	54,190	1-12	37-33
12	Goffint ..		Stroke 10 7 1/2	9-25 " 53,020	..	..	2	15 1/2	10 7 1/2	"	36,286	0-71	25-79



Table 76.—VENTILATING: *Duty of Furnaces at Collieries in Northumberland and Durham Coalfield.* (Cochrane.)

Name of Colliery.	Downcast Shaft.		Upcast Shaft.		Temperature of Air.						Volume of Air circulated per Minute.	Water Gauge in the Mine.	Coal consumed in 12 Hours.	Consumption of Coal per Hour per H.P. in the Air.
	Diam.		Depth.		Area of Furnace Grate.									
	ft.	yd.	ft.	yd.	sq. ft.	Fahr.	Fahr.	Return Air near Furnace.	Fahr.	Fahr.				
Rugeley .. ..	12	160	12	160	64	..	..	61	141	117	110	0.62	40	37.0
North Seaton ..	15½	250	9	266	72	68	70	65	225	206	186	1.10	91	49.2
Ryhope.. ..	15	508	10½	460	160	62	..	76	170	..	134	1.00	120	56.3

VENTILATING: *Cost of Supplying Air by Different Systems.*  
(Forster.)

The following are the figures obtained for 100 cub. metres per minute. The use of steam as a motive power, at a cost of 12*l.* 10*s.* per gross H.P. per annum, is assumed:—

Compressed air at 3 atmospheres excess pressure; velocity of current 10 metres per second, escaping at full pressure from the air-pipe, 230 mm. diameter, cost 923*5l.* per annum. The same using a Körting blower, and pipes 89 mm. in diameter, 1510*l.* The same using a compound engine, Root's blower, and pipes of 50 mm., 365*l.*

Branch current taken from main fan pressure, 0·001 atmosphere or 10 mm. water gauge; 2 metres per second velocity of current, pipes 1030 mm. diameter, 210*l.* This, on account of the low velocity of current and the large size of pipes, would be practically useless at the distance of 1000 metres from the fan.

Current produced by a special high speed fan at surface  $\frac{1}{40}$  atmosphere, or 250 mm. pressure, velocity per second 6 metres, pipe 585 mm., cost 380*l.*

Current of 10 metres per second at  $\frac{1}{10}$  atmosphere, 1033 mm. pressure, pipes 454 mm., produced by a series of two or three fans, or a cylinder blowing engine. The cost in the first case is 725*l.*, and in the second 870*l.* per annum; or, where the pressure is increased to  $\frac{1}{4}$  atmosphere, 1510*l.* and 1935*l.* These are, however, only approximations, from very restricted data.

Electric transmission of power to mine ventilators working at low pressure; no pipes required; old pit ropes used as conductor.

VENTILATING: *Formulae.*

- (1)  $t$  = temperature of air in downcast shaft.  
 $T$  = temperature of air in upcast shaft.  
 $D$  = depths of the shaft in ft.  
 $m$  = the periphery of the transverse section of the air-course in ft.  
 $s$  = the area of the section in ft.  
 $l$  = the length traversed by the current in ft.  
 $v$  = the velocity of the current in ft. per second.

$$v = 96 \sqrt{\frac{(T - t) D s}{T + 448}} \frac{1}{m l + 368 s}$$

- (2)  $C$  = length of downcast column.  
 $c$  = length of upcast ditto.  
 $T$  = number of degrees in excess of 32° F. in  $C$ .  
 $t$  = number of degrees in excess of 32° F. in  $c$ ,  
 $c = C \left( \frac{480 + t}{480 + T} \right)$ .

## LIGHTING.

Table 77.—LIGHTING: *Relative Cost of Artificial Illumination by different Systems at a Colliery raising 1000 tons a day.*

## Electric Light.

	c. p.	hours per day.	lamp hours per annum.
1. Pit head, 2 × 200 c. p. . . .	= 14 × 16 averaging	10	= 40,600
2. Winding engine, fan, boilers, pumps, &c. . . . .	= 12 × 16	10	= 34,800
3. Shops, offices, &c. . . . .	= 16 × 16	1½	= 6,960
4. Screens, sorting, &c., 4 × 200 c. p. . . . .	= 28 × 16	1½	= 12,180
5. Underground . . . . .	= 20 × 16	10	= 58,000
6. " (continuous lighting) . . . . .	= 10 × 16	24	= 69,600
	100 × 16		222,140

The total candle power is about 2124, though with electric light this will be more effective than with other lights, on account of the greater facilities for reflection. To get the I.P.H. per annum we may divide the total lamp hours by 10, since each 16 c. p. lamp takes  $\frac{1}{10}$  I.P. Allowing 10 lb. of slack coal per I.P.H. at 1s. 6d. per ton—

<i>Electricity.</i> —Coal, 100 tons, at 1s. 6d. . . . .	£	s.	d.
Renewals of lamps at 1500 hours' burning (they usually last for 2000 hours):—	7	10	0
2900 hours. 1. 2 × 200 c. p. lamps renewed twice at 18s. each . .	3	12	0
2900 " 2. 12 × 16 " " " 4s. " . .	4	16	0
435 " 3. 16 × 16 " " " ½ times " 4s. " . .	1	1	4
435 " 4. 4 × 200 " " " ½ " 18s. " . .	1	4	0
2000 " 5. 20 × 16 " " " twice " 4s. " . .	8	0	0
6960 " 6. 10 × 16 " " " four times " 4s. " . .	8	0	0
Interest and depreciation at 10 per cent. on capital outlay—200%. . .	20	0	0
Oil, water, waste, &c. . . . .	5	0	0
	£59	3	4

The total cost of electric lighting will therefore be about 60½ per annum, and this on 290,000 tons per annum will be 05d. per ton raised.

*Gas.*—With gas, the capital outlay may be taken, for main, pipes, and fittings, at about 150l.

At 3 c. p. per cub. ft. per hour, and 5 ft. per 15 c. p. lamp:—

	£	s.	d.
1. 40,600 lamp hours at 5 cub. ft. = 203,000 cub. ft.	25	7	6
2. 34,800 " " = 174,000 "	21	15	0
3. 6,960 " " = 34,800 "	4	7	0
4. 12,180 " " = 60,900 "	7	12	3
5. 58,000 " " = 290,000 "	36	5	0
6. 69,600 " " = 348,000 "	43	10	0

Taking the cost at 6d. per 1000 cub. ft. Total cost of gas	138	16	9
Interest and depreciation on 150l. at 10 per cent. . . . .	15	0	0

£153 16 9

*Gas*—continued.

On the same amount of coal per annum, viz. 290,000 tons, this will be about  $\cdot 13d.$  per ton raised.

*Paraffin*.—With paraffin, taking  $2 \times 1\frac{1}{2}$  in. wick duplex lamps as 16 c. p., consuming  $\frac{1}{10}$  pint of oil (at  $8d.$  per gal.) per hour.

					£	s.	d.
1.	40,600 lamp hours	=	507.5 gal.	.. .. .	16	18	4
2.	34,800 "	=	435 "	.. .. .	14	10	0
3.	6,960 "	=	87 "	.. .. .	2	18	0
4.	12,180 "	=	152.25 "	.. .. .	5	1	6
5.	58,000 "	=	725 "	.. .. .	24	3	4
6.	69,600 "	=	870 "	.. .. .	29	0	0
Total cost of oil .. .. .					92	11	2
Wick, say .. .. .					3	0	0
Labour, trimming, &c. .. .. .					25	0	0
Interest on capital outlay of, say, 80l. at 5 per cent. .. .. .					4	0	0
Depreciation, repairs, and breakages, at 20 per cent. on 80l. .. .. .					16	0	0

£140 11 2

On 290,000 tons raised, this amounts for oil to  $\cdot 116d.$  per ton, for gas to  $\cdot 13d.$  per ton, and for electricity to  $\cdot 05d.$  per ton.

Thus it will be seen that electricity compares very well as to cost with other illuminants, since gas costs nearly three times and oil more than twice as much for the same amount of illumination.

### *Thorneburry Miners' Safety Lamp.*

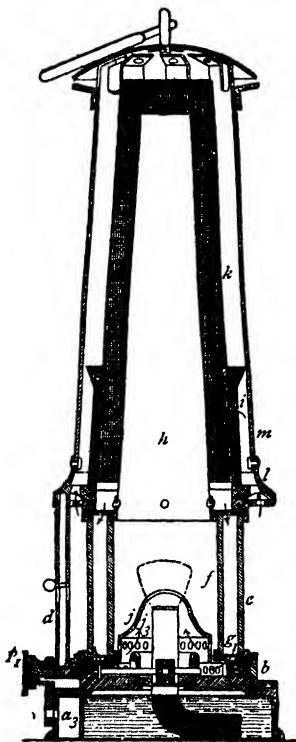
The Thorneburry lamp promises to exceed all previous lamps of the same class in the amount of light which it gives, and in the security which it will afford in an explosive atmosphere. The fuel of the lamp is heavy petroleum oil, having a flashing point of  $250^{\circ}$ , and it is burned under a cone of the familiar form which obtains in paraffin lamps. The whole of the air-supply is delivered into this cone, and most of it passes through the slot in the top, making a sharp draught, which steadies and brightens the flame. The illumination afforded is  $1-1\frac{1}{2}$  candles, which is three or four times that of a modern safety-lamp, a most valuable feature, as the miner's ability to detect dangerous spots in the roof depends to a great extent upon the amount of light at his command. The wick can be raised and lowered by a pinion and milled disc in the usual way, but as the gas given off by the oil does not burn in actual contact with the wick, the latter needs very little adjustment, and need not be disturbed for hours.

Referring to Fig. 10, it will be seen that the oil reservoir forms the base of the lamp, and is screwed into the ring *b*. This ring is connected to an upper ring by a number of columns *d*. Between the two rings are fixed two concentric glass cylinders *e f*, so secured that they are not disturbed when the lamp is taken to pieces for cleaning. To the top of the upper ring is screwed the chimney and its case. The air to support combustion enters

*Safety Lamp*—continued.

through holes in the upper ring, and passing the gauze screen *v* travels downwards between the glass cylinders *e f*. At the bottom it passes through a ring of gauze *g'*, and then through perforations in the base *b*, after which it enters the cone. The products of

Fig. 10.



Thornebury Safety Lamp.

combustion rise up the chimney *h*, and escape through openings at the top of the case, first passing through the gauze cone *k*. This latter, however, is not necessary for safety. The lamp is self-extinguishing in an explosive mixture, the gas and air entering the lamp cone being ignited by the flame and consumed before it reaches the chimney. Both the lamp flame and the ignited gas are automatically extinguished by the after-damp or carbonic acid gas, which is produced in the cone by the ignition of the explosive mixture. Hence it is obvious that the outer gauze enclosing the chimney is not necessary for the safety of the lamp, but is only an additional protection in case of an accident to the bottom gauze ring.

The top part of the lamp is locked by a bolt which stands over the pin *p*. So long as the latter is in position the bolt cannot be withdrawn. The pin *p* is again locked by a bayonet joint having a part which can be padlocked or riveted to the oil reservoir. When the locking is complete, the lamp cannot be opened without detection by any ingenuity.

The lamp has been tested by Sir F. Abel and Prof. Dewar, who report that they have conducted a series of laboratory experiments

with it, and have witnessed practical trials, which were carried out at the Aldwarke Main Colliery, by Mr. Rhodes, in an apparatus of the same character as was used by the last Royal Commission on Accidents in Mines. They saw the lamp tested in explosive gas mixtures, the velocity of the current being in some experiments as high as 50 ft. per second, or 3,000 ft. per minute; both horizontal

*Safety Lamp*—continued.

and inclined currents, upwards and downwards, were used. In all instances the lamp was extinguished within a very few seconds after the explosive gas current was established, and on no occasion during the course of the experiments was the combustible gas mixture within the lamp seen to burn. The lamp, therefore, fulfilled the conditions, even under abnormal circumstances, essential to safety in mines, as laid down in the Mines Commissioners' Report. A light of uniform power, which could be so regulated as to equal  $1-1\frac{1}{2}$  candle-power, was maintained for many hours with mineral oil of high-flashing point, which, in regard to safety, is not inferior to the animal or vegetable oils used, or to the mixture prescribed by the Mines Commission.

In regard to simplicity of construction, the lamp compares favorably with many of the later and more efficient forms of safety-lamps, and the several parts are readily maintained in a thoroughly clean and efficient condition.

Table 78.—COAL CUTTING: Comparison of Relative Cost by Hand and Machine. (G. Blake Walker.)

	In a Seam 36 in. thick.				In a Seam 30 in. thick.				In a Seam 24 in. thick.				In a Seam 18 in. thick.			
	Nature of Holing.		Nature of Holing.		Nature of Holing.		Nature of Holing.		Nature of Holing.		Nature of Holing.		Nature of Holing.		Nature of Holing.	
	Favour- able.	Hard.	s. d.	Very Hard.	Favour- able.	Hard.	s. d.	Very Hard.	Favour- able.	Hard.	s. d.	Very Hard.	Favour- able.	Hard.	s. d.	Very Hard.
Price for getting coal by hand, per ton .. .. .	1 6	1 7	s. d.	1 8	s. d.	2 0	s. d.	2 2	s. d.	2 6	s. d.	3 0	s. d.	3 3	s. d.	4 0
Percentage of slack by hand ..	40	40	45	20	45	20	50	20	50	25	55	25	55	30	55	30
Percentage of slack by machine ..	20	20	20	20	20	20	20	20	25	25	25	25	30	30	30	30
Average selling price per ton — Round (including nuts), at	s. d.	s. d.	s. d.	s. d.	s. d.	s. d.	s. d.	s. d.	s. d.	s. d.	s. d.	s. d.	s. d.	s. d.	s. d.	s. d.
6s. per ton .. .. . hand	4 7-2	4 7-2	4 5	4 5	4 5	4 5	4 5	4 3	4 3	4 3	4 1	4 1	4 1	4 1	4 1	4 1
Slack, at 2s. 6d. per ton machine	5 4	5 4	5 4	5 4	5 4	5 4	5 4	5 4	5 1½	5 1½	5 1½	5 1½	4 11½	4 11½	4 11½	4 11½
Price for filling out coal when coal is holed by machine ..	1 0	1 0	1 0	1 0	1 3	1 3	1 3	1 3	1 10	1 10	1 10	1 10	2 6	2 6	2 6	2 6
Yards holed by each machine ..	140	105	70	500	140	105	70	500	140	105	70	500	140	105	70	500
per day of 16 hours .. .. .	tons	tons	tons	tons	tons	tons	tons	tons	tons	tons	tons	tons	tons	tons	tons	tons
Holed by 7 machines per day, say	1,000	750	500	500	830	620	415	415	666	500	333	333	500	375	250	250
Holed by 7 machines in 250 days .. .. . say	250,000	190,000	125,000	125,000	207,500	155,000	102,750	102,750	166,500	125,000	83,250	83,250	125,000	93,750	62,500	62,500
Cost per ton (based on previous estimate) for holing by ma- chine .. .. .	s. d.	s. d.	s. d.	s. d.	s. d.	s. d.	s. d.	s. d.	s. d.	s. d.	s. d.	s. d.	s. d.	s. d.	s. d.	s. d.
0 3-1	0 4-2	0 6-3	0 6-3	0 6-3	0 3-8	0 5-1	0 7-6	0 7-6	0 4-8	0 6-3	0 6-3	0 9-5	0 6-3	0 8-4	0 8-4	0 6-6
Total cost of coal getting by machine .. .. .	1 3-1	1 4-2	1 6-3	1 6-3	1 6-8	1 8-1	1 10-6	1 10-6	2 2-8	2 4-3	2 7-5	2 7-5	3 0-3	3 2-4	3 2-4	3 6-6
Saving, as compared with hand labour .. .. .	0 2-9	0 2-8	0 1-7	0 1-7	0 3-2	0 3-9	0 3-4	0 3-4	0 3-2	0 4-7	0 4-5	0 4-5	0 2-7	0 4-6	0 4-6	5-4
Saving in yield of coal (value) Total saving .. .. .	0 8-8	0 8-8	0 11-0	0 11-0	0 11-0	0 11-0	1 1-0	1 1-0	0 10-5	0 10-5	1 0-5	1 0-5	0 10-5	0 10-5	0 10-5	10-5
	0 11-7	0 11-6	1 0-7	1 0-7	1 2-2	1 2-9	1 4-4	1 4-4	1 1-7	1 3-2	1 5	1 5	1 1-2	1 3-1	1 3-1	3-9

## HAULING AND HOISTING.

HAULING AND HOISTING: *Determination of Qualities and Strength of Ropes from Appearance.*

A good hemp rope is hard, but pliant, yellowish or greenish-grey in colour, with a certain silvery or pearly lustre. A dark or blackish colour indicates that the hemp has suffered from fermentation in the process of curing, and brown spots show that the rope was spun while the fibres were damp, and is, consequently, weak and soft in those places. Again, sometimes a rope is made with inferior hemp on the insides, covered with yarns of good material—a fraud, however, which may be detected by dissecting a portion of the rope, or, in practised hands, by its behaviour in use. Other inferior ropes are made from short fibres, or with strands of unequal length or unevenly spun—the rope in the first case appearing woolly on account of the number of ends of fibre projecting, and, in the latter case, the irregularity of manufacture is evident on inspection by any good judge. A very simple and extremely ready means for ascertaining the purity or otherwise of Manilla hemp consists in forming balls of loose fibre of the ropes to be tested, and burning them completely to ashes. While pure Manilla hemp burns to a dull greyish-black ash, Sisal leaves a whitish-grey ash, combinations of Manilla and Sisal yielding a mixed ash resembling the beard of a man turning from black to grey.

Table 79.—*Weights and Strengths of Hemp and Wire Ropes.*

## (a) FLAT ROPES.

Hemp.		Iron.		Steel.		Equivalent Strength.	
Size in inches.	Weight per fathom.	Size in inches.	Weight per fathom.	Size in inches.	Weight per fathom.	Working Load.	Breaking Load.
	lb.		lb.		lb.	cwt.	tons
4 + 1 $\frac{1}{2}$	20	2 $\frac{1}{2}$ + $\frac{1}{2}$	11	..	..	44	20
5 + 1 $\frac{1}{2}$	24	2 $\frac{1}{2}$ + $\frac{1}{2}$	13	..	..	52	23
5 $\frac{1}{2}$ + 1 $\frac{1}{2}$	26	2 $\frac{1}{2}$ + $\frac{3}{4}$	15	..	..	60	27
5 $\frac{3}{4}$ + 1 $\frac{1}{2}$	28	3 + $\frac{1}{4}$	16	2 + $\frac{1}{2}$	10	64	28
6 + 1 $\frac{1}{2}$	30	3 $\frac{1}{2}$ + $\frac{1}{4}$	18	2 $\frac{1}{2}$ + $\frac{3}{4}$	11	72	32
7 + 1 $\frac{1}{2}$	36	3 $\frac{1}{2}$ + $\frac{3}{4}$	20	2 $\frac{1}{2}$ + $\frac{1}{2}$	12	80	36
8 $\frac{1}{2}$ + 2 $\frac{1}{2}$	40	3 $\frac{3}{4}$ + $\frac{1}{2}$	22	2 $\frac{1}{2}$ + $\frac{1}{2}$	13	88	40
8 $\frac{1}{2}$ + 2 $\frac{1}{2}$	45	4 + $\frac{1}{2}$	25	2 $\frac{1}{2}$ + $\frac{3}{4}$	15	100	45
9 + 2 $\frac{1}{2}$	50	4 $\frac{1}{2}$ + $\frac{1}{2}$	28	3 + $\frac{1}{4}$	16	112	50
9 $\frac{1}{2}$ + 2 $\frac{1}{2}$	55	4 $\frac{1}{2}$ + $\frac{3}{4}$	32	3 $\frac{1}{2}$ + $\frac{1}{4}$	18	128	56
10 + 2 $\frac{1}{2}$	62	4 $\frac{3}{4}$ + $\frac{1}{2}$	34	3 $\frac{1}{2}$ + $\frac{3}{4}$	20	136	60



Table 79—continued.

## (b) ROUND ROPES.

Hemp.		Iron Wire.		Steel Wire.		Equivalent Strength.	
Circumference.	Weight per fathom.	Circumference.	Weight per fathom.	Circumference.	Weight per fathom.	Working Load.	Breaking Load.
in.	lb.	in.	lb.	in.	lb.	cwt.	tons.
2½	2	1	1	..	..	6	2
..	..	1½	1½	1	1	9	3
3½	4	1¾	2	..	..	12	4
..	..	1¾	2½	1½	1½	15	5
4½	5	1¾	3	..	..	18	6
..	..	2	3½	1¾	2	21	7
5½	7	2½	4	1¾	2½	24	8
..	..	2½	4½	..	..	27	9
6	9	2¾	5	1¾	3	30	10
..	..	2½	5½	..	..	33	11
6½	10	2¾	6	2	3½	36	12
..	..	2¾	6½	2½	4	39	13
7	12	2¾	7	2½	4½	42	14
..	..	3	7½	..	..	45	15
7½	14	3½	8	2½	5	48	16
..	..	3½	8½	2½	..	51	17
8	16	3½	9	2½	5½	54	18
..	..	3½	10	2½	6	60	20
8½	18	3½	11	2½	6½	66	22
..	..	3½	12	..	..	72	24
9½	22	3½	13	3½	8	78	26
10	26	4	14	..	..	84	28
..	..	4½	15	3½	9	90	30
11	30	4½	16	..	..	96	32
..	..	4½	18	3½	10	108	36
12	34	4½	20	3½	12	120	40

HAULING AND HOISTING: *Mine Ropes in England, Belgium, and Germany.* (Aguillon.)

With regard to the material for pit-ropes—whether hemp, or iron or steel wire—and their shape, whether round or flat—the advantage attributed to hemp ropes, of giving warning before they break, is shared equally by wire ropes when properly looked after, and the latter can be employed with as much safety as hemp ropes, when proper care is bestowed upon everything affecting their working. In wet pits, particularly where the water is at all corrosive, or where it is wound up in buckets instead of being pumped, aloes ropes are preferable. But in upcast-shafts, however slightly warm be the air-current, wire ropes should be used, in spite of the disadvantage of their hemp core. In the absence of any such special reasons, the choice of material is more a question of economy and convenience than of safety. Where it is determined that the rope

*Mine Ropes*—continued.

shall be flat instead of round, the power of the winding engine in deep pits can be better balanced with a hemp rope; because a flat wire-rope is too thin to alter the leverage quickly enough in coiling or uncoiling on the rope roll, and would involve some kind of counterbalance, which would be a matter of difficulty. This is the practical reason why several deep pits in France have recently changed from flat wire-ropes to flat aloes-rope. With wire-rope, too, there is much more difficulty in making a good flat rope than a good round one; and round ropes winding on conical or spiral drums afford a convenient means of balancing the engine-power. As to the choice between steel and iron for wire ropes, German and English practice goes to show that steel ropes well made and of a suitable quality of steel, are capable of working better in all respects, and appear even to be safer. The exclusive use of steel-wire ropes in Germany and England, and of hemp or aloes ropes in Belgium, for all depths of pit, is attributed to the degree of excellence which has been arrived at in the two former steel-producing countries in the manufacture of steel wire of sufficiently homogeneous quality and otherwise suitable for ropes; whereas in Belgium the manufacture of aloes or hemp ropes has always been a special industry of Flanders, where it has attained a rare degree of perfection. The whole of the winding gear should always be carefully adapted to the particular material of which the ropes are made. In France the mistake has generally been committed of ordering a rope without giving the maker any idea of the conditions under which it is to work, the very make being often specified for him in detail. Elsewhere the more sensible practice is to consult with the maker throughout, furnishing him with complete information as to the whole of the requirements to be fulfilled.

In addition to being tested, all ropes should be guaranteed by the makers. In Belgium the guarantee for aloes ropes is generally that they shall last  $1\frac{1}{2}$ –2½ years, or else for a given output; and 1-12th or 1-24th of their value is deducted for every month short of their stipulated duration. At the Royal Collieries at Saarbrücken, the ropes, of English crucible cast-steel wire, are guaranteed for 6 weeks, during which the maker is held liable to replace them if found defective.

Testing should apply, for hemp and aloes ropes, both to the raw material itself and to the spun yarn, as well as to sample lengths of the finished ropes. The twist of the rope, and the stitching of a flat rope, should be very uniform; and the rope should not contain more than 20 per cent of tar.

Iron wire for ropes should be strong, hard, pliable, and not galvanised, and should be selected from standard makes. Steel wire should be made from crucible cast-steel, of very homogeneous and comparatively hard quality, and suitably annealed; it should have a tensile strength of 70–76 tons per sq. in., and should stretch 3–5 per cent., and be pliable. It should be tested for tensile

*Mine Ropes—continued.*

strength, stretching, bending, and torsion; and all the wires in the same rope should be as closely alike as possible. Sample lengths of the rope itself should be tested. The lay of the wires and strands should be regular; in flat ropes the stitching should be regular, and should be done with annealed wire. Torsion is considered an excellent test for homogeneous quality in wire: steel wires of 0.509 in. and 0.118 in. diameter should stand twisting through 40 and 20 revolutions respectively in an unloaded length of 6 in.; and the surface markings produced by the twisting should follow regular lines.

The size of the wires, and the length of their lay or pitch in the rope, should vary in accordance with the diameter of the drums and pulleys round which the rope will have to work; and particularly with the distance between the drum and the pit-head pulley, and with the angle which the inclined span winding on the drum makes with the vertical portion hanging down the pit. These are essential points for determining the stiffness requisite to prevent the rope from flapping as it runs.

Experience proves that the very material itself of every rope does certainly undergo deterioration in working, thereby diminishing the rope's strength till it becomes no longer safe. This deterioration of material is something more than mere wear by friction or rusting; in aloes ropes, the fibres lose their strength; and in wire ropes, even where testing fails to show any loss of tensile strength per sq. in. of section, there is a clear diminution of pliability and elasticity; the wires become harsh and brittle, whereby the rope is weakened. Though the deterioration is generally accompanied by unmistakable external indications, it is yet desirable to trace its progress by actual tests of the individual wires, or of the ends of the rope itself.

Large diameters for drums and pulleys are of more importance for wire ropes than for hemp, and for steel than for iron. The smallest diameter should be at least 1300–1400 times that of the iron wire in a rope, and 2000 times that of the steel wire. Its relation to the size of the rope itself matters less, because the disadvantage of too small a diameter can be obviated by selecting a suitable size of wire and by a suitable make of rope. It is well, however, for the smallest diameter of pulley or drum to be not less than 80–100 times the diameter or thickness of a wire rope, and 50 times for a hemp rope.

The rope should wind smooth on the drums or pulleys, without rubbing sideways against them, and so as to run free from jolts and flapping. For wire ropes it is desirable to line the grooves of the pulleys with wood. The larger the diameter of the head-gear pulley, the less does it matter how small be the angle which the inclined span winding on the drum makes with the rope hanging down the pit; but with smaller diameters of pulley the angle should be increased, in order thereby to diminish the bending of the rope

*Mine Ropes—continued.*

in passing over the pulley. Opinions differ as to the minimum angle to be allowed; some assign  $40^\circ$  as the limit, while according to others it should never be less than  $60^\circ$ . In plan, the obliquity of a round rope between the overhead pulley and the drum should always be kept within the smallest possible limits.

In doubling back the rope end for attaching it to the cage, the loop should be kept as large as possible, by inserting within it an iron eye or a wooden disk; this is particularly advisable with iron wire-ropes, and still more so with steel. The attachment should also be made with springs, for easing the jerk at starting.

Iron or steel wire-ropes of large size should not work at more than one-tenth of their breaking strength; small round ropes may be worked up to one-sixth. Well-made aloes-ropes may be loaded to one-seventh or one-eighth.

Careful maintenance is indispensable to the preservation of all ropes, especially of wire-ropes. Hemp ropes want tallowing regularly, and aloes ropes want keeping always damped. Wire-ropes, steel particularly, should be greased regularly, and often enough to prevent their ever beginning to rust. The grease should be soft enough to work into the strands, right through the hemp cores, but stiff enough to stick on the outside of the rope. A mixture of oil and grease, well stirred and laid on hot with a brush, answers very well; both oil and grease should be neutral.

Iron wire ropes are rapidly being replaced by steel wire, owing to the less weight needed to afford the same strength. But it must be remembered that when the mine water contains much acid, the steel will wear much faster than the iron.

Table 80.—HAULING AND HOISTING: *Underground Haulage.*  
(N. Eng. Inst. Min. Engs.).

System of Haulage.	Average Gradient for Full Tubs.	Ropes or Chains.	Tubs.	Grease and Oil.	Coals.	Repairs to Engines and Boilers.	Maintenance of Way.	Labour.	Total.
Endless chain	Rise 1 in 59	0.083	0.173	0.155	0.256	0.072	0.068	0.572	1.379
Tail rope ..	" 1 " 213	0.276	0.114	0.186	0.558	0.098	0.064	0.583	1.879
Endless rope	" 1 " 36	0.252	0.309	0.138	0.323	0.196	0.083	1.692	2.993

### HAULING AND HOISTING : *Endless Chain Haulage.* (Mowat )

The speed of the chain varies from 1 to 3 miles per hour, the best speed being about 2 miles per hour, although this may be increased with advantage to 3 miles when the output is very large, and the chain is not strong enough to allow of the hutches being placed close together. The distance between the hutches varies from 10 to 25 yd., according to circumstances. If the road is very flat, they might require to be placed as close together as 10 yd. to get sufficient motive power, while, if the incline is steep, 25-30 yd. apart will give ample power. When the distance is greater than 25 yd., however, the chain is liable to trail on the pavement between the hutches, thus causing great tear and wear ; so that, if possible, the distance should be shortened that the chain may never touch the ground, except, perhaps, near the lower wheel, where it can hardly be avoided, and where beech planks should be laid to keep it off the pavement. The distance between the hutches is regulated by a small bell, which is placed on the incline at the prescribed distance from the hanging-on place, and which is rung by the last hung-on hutch striking it. The boy at the bottom puts on an empty hutch for every full one that comes off, thus keeping the number on both sides as nearly as possible uniform.

If the speed of the chain be taken as 2 miles per hour, and the distance between the hutches as 15 yd., the total number of hutches run off per hour, if the chain goes constant, would be  $\frac{2 \times 1760}{15} =$

$234\frac{2}{3}$  hutches per hour : or, if the hutches hold 10 cwt. each, 117 tons per hour. These figures show clearly that a very large output can be drawn, regardless of the length of the incline, without increasing the speed beyond a creeping pace.

When a change of gradient takes place, so as to form a hollow, the road must be raised in the hollow and the inclination changed gradually, so as to prevent the chain from being lifted out of the catch. In short, the road must be made to follow the natural curve of the chain. When a chain is suspended between two points of support, it forms a catenary curve, but if it is drawn nearly straight between the supports, it may be taken as a parabola, whose axis is vertical, without sensible error. In order to find the parabola which the chain will assume, it is necessary to take into account the tension of the chain at the origin or lowest point of the curve, the weight of the chain, and the distance between the hutches, all of which are known, or can easily be found.

Let  $T$  = tension at  $O$  in lb.

$w$  = weight of chain per ft. in lb.

$OH = y = \frac{1}{2}$  span between supports in ft.

$x$  = depression in ft.

$wy$  = approximate weight of chain  $OP$ , when  $OP$  is nearly straight and level.

*Endless Chains*—continued.

Then, to find the depression  $x$  in the chain between the two hutches,

$$\begin{aligned}\frac{x}{\frac{1}{2}y} &= \frac{wy}{T} \\ x &= \frac{wy^2}{2T},\end{aligned}\quad (1)$$

and the equation to a parabola, when  $y$  and  $q$  are the co-ordinates and  $4A$  the ratio between  $x$  and  $y^2$ , is

$$y^2 = 4Ax,$$

but from (1)

$$\begin{aligned}y^2 &= \frac{2T}{w}x, \\ \therefore 4A &= \frac{2T}{w},\end{aligned}$$

The curve is, therefore, a parabola, the equation to which is

$$Y^2 = \frac{2T}{w}x.$$

Again, if it is desired to find the distance from the origin  $O$  of the parabola to the tangent  $K$ , where the curve will join a straight line  $KL$ , let the inclination of the line be expressed as the tangent of the angle  $KLN$ , that is, the vertical height divided by the horizontal distance—e. g. 1 in 5 =  $\cdot 20$ , 1 in 3 =  $\cdot 3$ .

Then

$$\tan KON = \frac{\tan KLN}{2}$$

$$\frac{x_1}{y_1} = \frac{\tan KLN}{2},$$

but

$$x_1 = \frac{y_1^2}{4A},$$

therefore

$$y_1 = \frac{4A \times \tan KLN}{2},$$

and

$$4A = \frac{2T}{w}. \quad (2)$$

$$\therefore ON = y_1 = \frac{T \times \tan KLN}{w}. \quad (3)$$

*Endless Chains—continued.*

Again, to find the tension, in another place referred to as carrying tension, which must be applied in order that the chain may not trail on the ground:

$$x = \frac{w y^2}{2 T} \quad (1)$$

$$\therefore T = \frac{w y^2}{2 x} \quad (4)$$

Of course,  $x$  must be a less distance than the height of the point of support on the hutch above the ground.

For an output of 700 hutches per day, the following oncost would be required to keep the chain going, viz.:—One man at the top, hanging on loaded hutches; one boy at the top, attending to the brake; one boy at the bottom, hanging on empty hutches; while the expense of upkeep of the incline would not be nearly so great as in an ordinary incline worked by a rope, owing to the speed being so low. To reduce the cost of attendance as much as possible, the inclinations should be arranged so that the empty hutches arriving at the top will detach themselves and run forward into the lye, for further transit by horses or drawers; while the full hutches will detach themselves at the bottom end and run forward to the pit-bottomer, or into a lye if the foot of the incline is not near the pit-bottom. When the output is small, so as to allow of the chain going at a slow speed, the brakesman may be dispensed with, the benchman being able to hang on and look after the brake as well.

The flattest inclination at which an incline of this kind will self-act depends on the comparative weights of full and empty hutches, on the weight of the chain, and on the friction of the hutches and chain wheels. As the chain should not touch the ground, there is no friction due to it, except that at the chain wheels, and the extra friction which its weight causes on the hutch wheels.

If  $W$  denotes weight of full hutches and chain on full side.

“ “ “ empty “ “ empty side.

“  $F$  “ friction of hutches, chain, and wheels on full side.

“  $f$  “ “ “ “ empty side.

“  $I$  “ tangent of angle of inclination, or inclination expressed as a fraction—i. e. for 1 in 60— $I = \frac{1}{60}$ .

Then, before the incline will self-act,

$$(W \times I) - F \text{ must be greater than } (w \times I) + F$$

$$(W - w) I > F + f$$

$$I > \frac{F + f}{W - w}$$

The inclination found from the above formula would be that on

*Endless Chains*—continued.

which the surplus power of the full side would just balance all the resistances, so that the incline would require to be steeper than this in order that it might self-act.

The friction would require to be assumed or found by experiment, while the proper size of chain may be found from the formula,

$$D = 3 \sqrt{\text{breaking strain in tons}}; \text{ or}$$

$$D = 3 \sqrt{\text{working load} \times S},$$

D being the diameter of chain in sixteenths of an inch, and S being the factor of safety, which should be at least 5.

The working load on the chain is the greatest tension T, which is

$$T = (W \times l) - F + \text{carrying tension}.$$

The chain should not be short-linked, as the chain-plate becomes fixed between the links of a short-linked chain, and tends to prevent the hutches from detaching automatically.

In an ordinary self-acting incline the road must be more or less uniform in gradient, for if steeper in some parts than in others the train must be run over the steep portion with great velocity in order that it may acquire sufficient momentum to carry it through the flatter portion; while in a great many cases it is impossible to work an incline by trams at all if the flat portion of the road happens to be at the top and the steep portion at the bottom, as a start cannot be obtained.

In working with a self-acting endless chain, if the average inclination of the road is not less than 1, as found from the formula, the incline will work no matter how undulating it is, provided the average inclination is calculated from the total length of the road, and not from the horizontal distance on the section. The surplus power on a steep mine may be utilised for the purpose of drawing from a dock or level, not necessarily in the same straight line, by fitting the top wheel with a long shaft and putting on it a second driving wheel, or clip pulley, or rope drum provided with a clutch. In the same way water may be pumped, or almost any description of work done, if the power be sufficient.

The advantages which a self-acting endless chain possesses over an ordinary incline may be summed up shortly as follow:—

(1) Small cost of upkeep of rolling stock, owing to slow speed causing few breakages. When a hutch goes off the road the chain stops.

(2) Regularity of delivery. The hutches arrive at the pit-bottom in such a manner that only very short lyes are required, and consequently the travel of the bottomers is diminished.



*Endless Chains—continued.*

(3) When the output exceeds 100 tons a day, and probably before it, it can be worked much cheaper than an ordinary self-acting incline.

(4) Length makes no difference in the output or cost further than the increased upkeep of the road, whereas the difficulties in the way of drawing with a "cousie" increase with the length.

(5) Much less expenditure is required in making benches, as no long trains require to be collected on the incline as in a cousie.

(6) The cost for chains is less than for ropes, as a good chain will last 12-18 years.

HAULING AND HOISTING: *Electrical Haulage.* (Tallis.)

The various losses in an economical installation should not exceed the figures in Table 81 to obtain 20 H.P. in the ropes of the two branches respectively.

Table 81.

	Per cent.	On H.P.	Loss in H.P.	Electric Loss H.P.	Mechanical Loss H.P.
1. Loss between steam-engine and terminals of generator, or in belting and generator .. .. .	20	80	16	6.0	10.0
2. Loss in cable to No. 1 motor .. ..	10	64	6.4	6.4	..
3. Loss in No. 1 motor .. .. .	10	27.95	2.8	2.8	..
4. Loss in gearing between No. 1 motor and rope .. .. .	20	25	5.0	..	5.0
5. Loss in cable from No. 1 to No. 2 motor .. .. .	6	29.65	1.7	1.7	..
6. Loss in No. 2 motor .. .. .	10	27.95	2.8	2.8	..
7. Loss in gearing between No. 2 motor and rope .. .. .	20	25	5.0	..	5.0
Total loss .. .. .	..	..	39.7	19.7	20.0

The summary of the losses being nearly 40 H.P., it would require a steam-engine of 80 H.P. on surface to provide 40 H.P. in the haulage-ropes underground, an efficiency of 50 per cent., which will compare favourably with any existing system under the same conditions. It is possible that this efficiency can be considerably increased, and probably will be; however, there should be no difficulty in getting engineers to guarantee the above efficiency.

HAULING AND HOISTING: *Electrical Haulage.* (Tallis.)

Approximate cost of plant for installation of two 30-H.P. electric motors, situate respectively at 2500 and 2000 yd. distant from the generating station on surface.

Two single horizontal 15-in. cylinder engines, coupled, stroke 30 in., with 12 ft. fly-wheel to receive driving-belt, automatic governor, expansion gear, and side-feed lubricator to each cylinder .. .. .	£	s.	d.
Driving belt, 16 in. diameter, leather .. .. .	500	0	0
Dynamo to give 56,000 watts at 500 volts and 480 revs. per minute, current and potential indicators, cut-outs, switches, &c. ....	60	0	0
4000 yards sheathed cable, equivalent to 0.5 in. diameter, solid copper rod, consisting of 37 strands of tinned copper wire, covered with one lap of pure and two layers best vulcanising rubber-coated rubbered tape, and the whole vulcanised together, further served with jute and sheathed with 20 galvanised iron wires, 0.169 in. diameter, and finally coated with three coats compound and two reserve tapes; finished diameter 1.48 in. ..	500	0	0
1020 yards sheathed cable, equivalent to 0.317 in. diameter, solid copper rod, consisting of 19 strands tinned copper wire (insulation as above), sheathed with 20 galvanised iron wires 0.131 in. diameter, finally coated and taped; finished diameter 1.18 in. ....	1200	0	0
Two 30-H.P. motors, at 420 revs. per minute, absorbing about 23,000 watts .. .. .	180	0	0
	600	0	0

Foundations, engine-houses, steam-pipes from boilers, labour, drums, gearing, and erection, extra.

HAULING AND HOISTING: *Electrical Haulage.* (Lebreton.)

At Zaukeroda experiments have been made to determine the efficiency of the system. As measured between the indicated power of the steam-engine driving the generator, and the useful work done by the locomotive, it is 30 per cent.; as measured between the power absorbed by the generator and the power absorbed by the motor, it is 46.6 per cent. The cost of working is given as: 11s. 9d. for 660 wagon-loads in 16 hours, to which must be added 8s. 1d. for interest and depreciation at the rate of 15 per cent., making a total of 19s. 10d., or 0.36d. per wagon.

Table 82 shows the cost as compared with previous results for traction by horses and men:—

Table 82.

	Cost of Electrical Traction, including Depreciation.	Cost of Horse Traction.	Cost of Traction by Men.
For 660 wagons .. ..	d. 0.36	d. 0.45	d. 0.74
	Reduced to ton-miles.		
" " .. ..	2.0	2.5	4.1

Table 83.—HAULING AND HOISTING : Comparison of Haulage Systems. (Schutz.)

	Rope on Drum at Antioch.	Trailing Cable at Saarbrücken.	High-Speed Windless Cable at Shire Oaks, Nottingham.	Low-Speed Windless Cable at Bridge Pit, Wigan.	Low-Speed Windless Cable at Meadow Colliery, Wigan.	Endless Chain at Saarbrücken.	Endless Chain at Mine, Haasard, Belgium.	Steam Locomotive at Louvain.	Steam Locomotive at Cresson.	Compressed Air, Beckan System.	Compressed Air, Mekarski System.	Electricity at Zaukeroda.
Cost of installation	£ 1600	2300	750	2300	750	4000	5600	1600	1600	650	1000	800
Interest and depreciation per ton-mile	d. 1.38	0.26	0.28	0.37	0.40	0.79	0.23	0.42	0.15	0.80	0.32	0.45
Cost of working per ton-mile	d. 0.53	1.02	1.82	3.71	2.02	0.74	0.22	0.60	0.52	1.20	1.35	1.11
Total cost per ton-mile	d. 1.91	1.28	2.10	4.03	2.42	1.53	0.45	1.02	0.67	2.00	2.17	1.56
Daily ton-miles	93	708	200	491	145	429	1320	293	867	65	97	143
Distance traversed..	600 yd.	4110	920	2163	638	1920	3500	2530	5041	676	676	676
Speed	330 yd. per minute	220	220	40	33	123	100	151	220	100	100	172
Weight of locomotive	.. tons	..	..	..	..	..	..	4.4	8	2.7	2.3	1.6

The increased cost of ventilation of the mine, when a steam locomotive is used, is not taken into account.

Table 84.—HAULING AND HOISTING: *Comparison of Haulage Systems.* (Lebreton.)

System.	Tons drawn per Shift.	Length of Line.	Cost per Ton-mile.
		yards.	d.
Tail rope .. .. .	480	2130	1·15
Endless rope .. .. .	429	1050	1·25
Floating cable .. .. .	403	850	0·83
Trailing " .. .. .	325	1400	2·01
Cable in Cadzow Colliery, Hamilton ..	842	1310	1·33
Electrical .. .. .	..	..	0·9

Table 85.—HAULING AND HOISTING: *Comparative cost of the various haulage systems reduced to a tonnage of 400 tons over a distance of 2200 yd., interest and depreciation at 15 per cent. on first cost being allowed for.* (Vogel.)

	d.
1. Self-acting chain .. .. .	0·45 per ton-mile.
2. Electrical locomotive .. .. .	0·88 "
3. Endless chain .. .. .	1·31 to 1·46 "
4. Various systems of traction by cables	1·66 ,, 2·00 "
5. Horses .. .. .	3·24 "

HAULING AND HOISTING: *Winding Engines.* (Haswell.)

With winding engines, for drawing coals, etc., out of a pit, where it is required to give a certain number of revolutions, it is necessary to have given diameter of drum and thickness of rope, which is flat made, and contrariwise.

*To Compute Diameter of a Drum, where Flat Ropes are used and are wound one part over the other.*

Rule.—Divide depth of pit in in. by product of number of revolutions and 3·1416, and from quotient subtract product of thickness of rope and number of revolutions; remainder is diameter in in.

Ex.—If an engine makes 20 revolutions, depth of pit being 600 ft. and rope 1 in., what should be diameter of drum?

$$\cdot 1 \times 20 = \frac{7200}{62 \cdot 832} - 20 = 94 \cdot 59 \text{ in.}$$

*To Compute Diameter of Roll.*

Rule.—To area of drum add area or edge surface of rope; then ascertain, by inspection in table of areas, or by calculation, diameter that gives this area, and it is the diameter of roll.

*Winding Engines*—continued.

Ex.—What is the diameter of roll in preceding example?

Area of  $94 \cdot 59 = 7027 \cdot 2 + (\text{area of } 7200 \times 1) = 7200 = 14227 \cdot 2$ ,  
and  $\sqrt{14227 \cdot 2 \div \cdot 7854} = 151 \cdot 85$  in.

Or, radius of drum is increased number of revolutions multiplied  
by thickness of rope; as  $\frac{94 \cdot 59}{2} + 20 \times 1 = 67 \cdot 295$  in.

*To Compute Number of Revolutions.*

Rule.—To area of drum add area of edge surface of rope; from diameter of the circle having that area subtract diameter of drum, and divide remainder by twice thickness of rope; quotient will give number of revolutions.

Ex.—Length of a rope is 2600 in., its thickness 1 in., and diameter of drum 20 in.; what is number of revolutions?

Area of  $20 + \text{area of rope} = 314 \cdot 16 + 2600 = 2914 \cdot 16$ , diameter  
of which is  $60 \cdot 91$ , and  $\frac{60 \cdot 91 - 20}{1 \times 2} = 20 \cdot 45$  revolutions.

Or, subtract diameter of drum from diameter of roll, and divide remainder by twice thickness of rope; as  $60 \cdot 91 - 20 = 40 \cdot 91$ ,  
and  $40 \cdot 91 \div 1 \times 2 = 20 \cdot 45$  revolutions.

*To Compute Point of Meeting of Ascending and Descending Buckets when two or more are used.*

*To Compute Point of Meeting of Buckets.* Rule.—Divide sum of length of turns of rope by 2, and to quotient add length of last turn; divide sum by 2, multiply quotient by half number of revolutions, and product will give distance from centre of drum at which buckets will meet.

Note 1.—Meeting will always be below half depth of pit.

2.—At half number of revolutions buckets will meet.

Ex.—Diameter of a drum is 9 ft., thickness of rope 1 in.; and revolutions 20; what is depth of pit, and at what distance from top will buckets meet?

*To Compute this Depth.* Rule.—To diameter of drum add thickness of rope in ft. and ascertain its circumference; to diameter of drum add quotient of product of twice thickness of rope and number of revolutions less 1, divide by 12 for a diameter, and circumference of this diameter is length of last turn, also in ft.; add these two

*Winding Engines*—continued.

lengths together, multiply their sum by half number of revolutions, and product will give depth of pit.

$$9 + \text{thickness of rope} = 9 + \frac{1}{2} \text{ of } 1 = 9.083, \\ \text{which} \times 3.1416 = 28.54 \text{ ft.} = \text{length of first turn.}$$

$$9.0833 + \frac{1 \times 2 \times 20 - 1}{12} \times 3.1416 = 38.48 \text{ ft.} = \left\{ \begin{array}{l} \text{length of} \\ \text{last turn.} \end{array} \right.$$

$$\text{Then } 28.54 + 38.48 \times \frac{20}{2} = 67.02 \times 10 = 670.2 \text{ ft., depth of pit.}$$

*Winding Engines with Flat Ropes coiled on Drum.* (Molesworth.)

To find the place of meeting for ascending and descending skips:—

$t$  = thickness of rope in inches.

$n$  = number of revolutions of the drum.

$x$  = the distance below half the depth of the pit at which the skips will meet in yd.

$$x = .0218 n^2 t.$$

To find the diameter of the winding barrel for flat ropes:—

$P$  = Depth of pit in ft.

$R$  = Number of revolutions of engine.

$T$  = Thickness of rope (in.).

$D$  = Diameter of winding barrel in ft.

$$D = \frac{12 P - 3.15 R^2 T}{37.7 R}.$$

*Safe Load on Chains.* (Molesworth.)

$D$  = Diameter in eighths of an inch.

$W$  = Safe load in tons.

$$D = \sqrt[3]{9 W}.$$

$$W = \frac{D^3}{9} = 7.111 d^3, \text{ where}$$

$d$  = Diameter of iron in inches.

Table 86.—*Working Load of Chains.* (Molesworth.)

Diam. in. . . . .	$\frac{1}{4}$	$\frac{5}{16}$	$\frac{3}{8}$	$\frac{7}{16}$	$\frac{1}{2}$	$\frac{9}{16}$	$\frac{5}{8}$	$\frac{11}{16}$	$\frac{3}{4}$
Load . . . . .	.44	.70	1.0	1.36	1.78	2.25	2.78	3.36	4.0
Diam. in. . . . .	$\frac{1 \frac{1}{8}}$	$\frac{7}{8}$	$\frac{3 \frac{1}{8}}$	1	$1 \frac{1}{8}$	$1 \frac{1}{4}$	$1 \frac{3}{8}$	$1 \frac{1}{2}$	$1 \frac{3}{4}$
Load . . . . .	4.69	5.44	6.25	7.11	9	11.11	13.44	16.0	21.78

Table 87.—*Mule, Tailrope, and Electrical Haulage compared.*  
(Pocock.)

(a) <i>Mule Haulage.</i>								First Cost.	£
16 large mules at 35 <i>l.</i> each	..	..	..	..	..	..	..	560	
16 sets of harness at 4 <i>l.</i>	..	..	..	..	..	..	..	64	
									<hr/>
								624	
Interest, Depreciation, &c.									
20 % depreciation on 560 <i>l.</i> ..	..	..	..	..	..	..	..	112	
6 % interest..	..	..	..	..	..	..	..	33	
									<hr/>
								145	
Working Expenses for 260 days.									
16 mules, harness, shoeing, feed, care, at 1 <i>s.</i> 3 <i>d.</i> per diem	..								260
8 drivers at 7 <i>s.</i> per day	..	..	..	..	..	..	..	728	
									<hr/>
Total yearly expense								..	1133
Or, on 260,000 tons yearly, 1·045 <i>d.</i> per ton.								<hr/>	

<i>(b) Tailrope Haulage. First Cost.</i>									
Pair of 14 × 20 in. engines, 150 rev. a minute	..	..	..	..	..	..	..	..	400
18,000 ft. of 1 in. steel rope	..	..	..	..	..	..	..	..	691
150 rollers, 8½ × 7¾ in.	..	..	..	..	..	..	..	..	137
100 sheaves 2 ft. diam., and 1 sheave 6 ft.	..	..	..	..	..	..	..	..	340
Cost of erection, &c.	..	..	..	..	..	..	..	..	200
Boilers	..	..	..	..	..	..	..	..	300
									2068
Interest, Depreciation, &c.									
6 % on 2068l.	..	..	..	..	..	..	..	..	124
Engine, depreciation 10 %, repairs 5 %	..	..	..	..	..	..	..	..	60
Boilers	..	..	..	..	..	..	..	..	45
Ropes, life 1 year	..	..	..	..	..	..	..	..	691
Sheaves, life 2 years	..	..	..	..	..	..	..	..	170
Rollers, life 1 year	..	..	..	..	..	..	..	..	137
									1227
Working Expenses for 260 days.									
Engineer at 10l. a month	..	..	..	..	..	..	..	..	120
Boiler attendance	..	..	..	..	..	..	..	..	60
Trip rider, at 7s. a day	..	..	..	..	..	..	..	..	91
Oil and waste	..	..	..	..	..	..	..	..	60
									1558
Total yearly expense									
Or, on 260,000 tons yearly, 1·438d. per ton.									

Table 87.—*continued.*

(c) <i>Electrical Haulage.</i> First Cost.										£
Engine, generator, and motor	..	..	..	..	..	..	..	..	..	2500
Boiler	..	..	..	..	..	..	..	..	..	200
Wire, insulators, switches, &c.	..	..	..	..	..	..	..	..	..	260
Labour of erection	..	..	..	..	..	..	..	..	..	250
										<hr/> 3210
Interest, Depreciation, &c.										<hr/>
Interest, 6 % on 3210 <i>l.</i>	..	..	..	..	..	..	..	..	..	192
Depreciation on moving parts, 10 % on 2700 <i>l.</i>	..	..	..	..	..	..	..	..	..	270
Repairs on moving parts, 8 %	..	..	..	..	..	..	..	..	..	216
Depreciation on standing parts, 6 % on 510 <i>l.</i>	..	..	..	..	..	..	..	..	..	31
Repairs on standing parts, 6 %	..	..	..	..	..	..	..	..	..	31
										<hr/> 740
Working Expenses for 260 days.										
Engineer at surface, at 10 <i>l.</i> a month	..	..	..	..	..	..	..	..	..	120
„ on motor, at 8 <i>s.</i> a day	..	..	..	..	..	..	..	..	..	104
Trip rider, at 5 <i>s.</i> 4 <i>d.</i> a day	..	..	..	..	..	..	..	..	..	70
Oil and waste	..	..	..	..	..	..	..	..	..	30
Sand	..	..	..	..	..	..	..	..	..	20
										<hr/> 1081
Total yearly expense										<hr/>
Or, on 364,000 tons, 0.715 <i>d.</i> per ton.										<hr/>

Table 88.—*Tests showing Extra Stress upon a Hoisting-Rope due to a Few Inches of Slack Rope. (Roberts.)*

<i>First Test.</i>										Strain in lb
No. 1, empty cage lifted gently	..	..	..	..	..	..	..	..	..	4,030
No. 2, „ „ „ „ „ „ „ „ „ „	..	..	..	..	..	..	..	..	..	4,030
No. 1, with 2½ in. slack rope	..	..	..	..	..	..	..	..	..	5,600
No. 2, „ 2½ „ „ „ „ „ „ „ „	..	..	..	..	..	..	..	..	..	5,600
No. 1, „ 6 „ „ „ „ „ „ „ „ „	..	..	..	..	..	..	..	..	..	8,950
No. 2, „ 6 „ „ „ „ „ „ „ „ „	..	..	..	..	..	..	..	..	..	8,950
No. 1, „ 12 „ „ „ „ „ „ „ „ „	..	..	..	..	..	..	..	..	..	12,300
No. 2, „ 12 „ „ „ „ „ „ „ „ „	..	..	..	..	..	..	..	..	..	12,300
<i>Second Test.</i>										
Cage and four empty cars weighed by machine										6,375
No. 1, cage lifted gently	..	..	..	..	..	..	..	..	..	6,725
No. 2, „ „ „ „ „ „ „ „ „ „	..	..	..	..	..	..	..	..	..	6,725
No. 1, with 3 in. slack rope	..	..	..	..	..	..	..	..	..	11,200
No. 2, „ 3 „ „ „ „ „ „ „ „ „	..	..	..	..	..	..	..	..	..	11,200
No. 1, „ 6 „ „ „ „ „ „ „ „ „	..	..	..	..	..	..	..	..	..	12,250
No. 2, „ 6 „ „ „ „ „ „ „ „ „	..	..	..	..	..	..	..	..	..	12,250
No. 1, „ 12 „ „ „ „ „ „ „ „ „	..	..	..	..	..	..	..	..	..	15,675
No. 2, „ 12 „ „ „ „ „ „ „ „ „	..	..	..	..	..	..	..	..	..	15,675





*Koepe Winding*—continued.

time, causing a large waste of energy. The Koepe system of winding has been adopted at Oberhausen and Westhausen in Westphalia, Stassfurth, in Upper Silesia, and Bestwood and Sneyd collieries in England, but has been abandoned at Oberhausen and Westhausen, possibly because breakage of one rope would cause the stoppage of both sides of the pit. After seven years' successful working, Koepe's system has been lately abandoned at Bestwood for two reasons: the management do not consider it safe, and slipping of the rope takes place every time it is oiled; this slipping commences immediately oil is applied, and after a time ceases altogether, to re-start, however, at the next oiling. This action is very objectionable at Bestwood, for, as before stated, the engineman has to rely entirely on the indicator for landing the cages, as he cannot see them when they reach the surface, owing to the top of the shaft being cased in. Against these abandonments we have the fact that no accident has occurred at the Hanover pit since the installation was put down in 1877; indeed, the life of winding-ropes is increased as before stated. The system is also giving every satisfaction at the Sneyd colliery in North Staffordshire.

HAULING AND HOISTING: *Hoisting in the Future* (Wheeler).

Theory indicates that tapered ropes have no limit in depth, and consequently that, by tapering and counterbalancing, ropes may be used in the deepest mines; but practically, in using flat ropes with reels, as now made, there is great risk of the rope slipping off the top coils and jamming down in the narrow V-space between the side of the reel and the coiled rope, with dangerous consequences, if the rope tapers to half its extreme width. By using a guide-sheave to wind the rope hard against one side of the reel, this danger may be overcome, though at the expense of more rapid wear of the rope, especially of the lacing. Flat ropes are now successfully and easily made of tapering section, and perhaps a better device can be used than the guide roller, to avoid jamming in the reel.

Round ropes are made tapering, and if the drum is grooved to properly receive the rope, it gives no trouble in winding like the flat rope. But American rope-makers do not advocate round tapering ropes, on account of the difficulty of manufacturing with perfect reliability.

If tapered ropes are ignored on account of their greater cost, and because of the objections of manufacturers, cylindrical ropes may still be used for unlimited depth by submitting to the low efficiency of the system when adopted at very deep shafts, necessitating a break of journey. While such a system of establishing interposed hoisting stations, with engines run by compressed air, whenever the rope becomes inconveniently long, can be carried on indefinitely, the outlay for plant becomes so great, the extra labour and time

*In the Future—continued.*

involved in changing cages at the intermediate levels are so expensive, and the efficiency of a compressor-plant is so low, with its consequent heavy fuel consumption, that the cost of installation and the operating expenses are enormous.

The simple, first-motion, cylindrical rope-hoist, constructed with the latest improvements, possesses the advantages of a minimum cost of installation, the cheapest operating plant, and the greatest capacity of all known systems of hoisting. The following suggestions show where it may be improved.

(a) By Counterbalancing the Dead Load.—If the system is arranged duplex, or with a double-compartment shaft, the dead loads of the cage and cars counterbalance one another; and if the ropes are counterbalanced, which is perfectly effected by an under-rope, then there remains only the work of raising the coal or live load plus the small effort necessary to overcome the friction due to the dead load (rope, cage, cars). Hence only a moderate-sized engine is called for, instead of the large engines so frequently seen at deep mines.

(b) By Using a Smaller Factor of Safety for the Rope.—For hoisting ropes, the factor of safety should be made as low as possible, consistent with uncertainty in manufacture, abuse in use, sufficient margin to permit the reduction in section due to wear, and a working-strain safely below the limit of elasticity. The larger the factor of safety used, the greater is the section of the rope for a given load. This increases the dead load due to the rope's own weight, which even if counterbalanced augments the mass to be put in motion each trip, with the consequent strain in starting. The increased size of the rope decreases its life, as the greater the diameter, other things being equal, the more severe are the bending strains and the quicker the rope destroys itself. The factor of safety usually taken for steel ropes is 7, with 5 as a minimum and 10 as a maximum. For standard practice I would advise 4, provided—that the diameter of the sheaves and drums be *at least* 100 times the diameter of the rope for slow hoisting, and *at least* 150 times for fast hoisting; that a spring be interposed between the cage and the rope-capping, to ease the sudden strain in starting; that the rope be kept properly oiled; and that the rope be inspected daily for its entire length, for careful observation of the condition of the wires and prompt rejection of the rope when a certain number are broken.

Lagging the sheave with wood, having the engine set far enough from the shaft to avoid side-thrust and consequent lateral wear of the rope at the sheave and drum (carrying the rope on wooden rollers from the sheave to the engine if necessary), and carefully maintaining the entire hoisting-plant in proper alignment, will prolong the life of the rope in spite of the smaller factor of safety; and thus the safe working-length of a  $1\frac{1}{2}$  in. cast-steel rope, when sustaining a 3-ton cage-load, may be increased from 3000 to 7500 ft.

*In the Future—continued.*

By decreasing the speed of hoisting, the wear of a wire rope is diminished; but this necessitates increasing the load to maintain a given output in the same time. Aside from the other disadvantages of excessive load, the maximum size of the cars used is frequently fixed by conditions that it is not economical to change in order to use large cars. Hence the more rapid wearing out of the ropes due to high speed in deep hoisting is willingly tolerated, in order to secure the capacity and economy due to fast hoisting; and the tendency of the times is to use larger and more powerful engines in order to obtain higher speeds as the mines become deeper; so that this method of prolonging the life of a rope is not in favour at present.

(c) By Use of Best Material for the Rope.—Very soft steel ropes possess the greatest flexibility, but they are deficient in strength, as the material has a breaking-strength of only about 60,000 lb. to the sq. in. The best grade of plough-steel, on the contrary, has a strength of 300,000 lb. per sq. in., but does not always give satisfaction as used with sheaves only 50-100 times the diameter of the rope, since the wires break too readily under such sharp bending. But if used with sheaves and drums 150-200 times the diameter of the rope, and if the wires are laid at an easy pitch with the "Lang lay," no such trouble should arise. With such a high-grade plough-steel rope of  $1\frac{1}{2}$  in. diam., the safe working-length, using a factor of safety of 4, would now be about 30,000 ft., or 12,500 ft., with 10 as the factor of safety. The very low specific gravity of aluminium, 2.6, which is about one-third of that of steel, and its great strength, make it an ideal metal for a deep-hoisting rope, where a minimum of weight and a maximum of strength are demanded. If this metal or its alloys should prove to have the requisite flexibility, toughness, and strength, to make a reliable, durable hoisting-rope, the question of deep-hoisting with only cylindrical ropes is again settled beyond all cavil.

(d) By Designing the Cage with a Minimum of Weight.—As mines get deeper, economy demands the use of 3- or 4-, or even 6-deck cages. The prevalent objection to multiple-deck cages is the time required in decking, even if the decking is carried on simultaneously from two landings or levels. To deck from more than two or at most three landings or levels at once makes the stations very complicated underground, and is not desirable, even should the surface-plant be so arranged that there is no objection to having the ore or coal coming off on two or three levels. But with facilities for accommodating both loaded and empty cars at the landings, with sufficient help to quickly handle the cars, there is nothing to prevent loading and unloading a 6-deck cage in 30 seconds, or 5 seconds per deck. A multiple-deck cage, with only one car on a deck, can be designed of steel, with a very light, and yet stiff strong frame, in which the ratio of the cage-weight to that of its contents is very low.

*Safety Cages.*

The safety of the miner does not depend only on the description of safety-cage used, but also on the care which is taken to keep it in order, the reliability of the springs, the evenness, strength, and size of the runners, and the condition generally of the shaft. Cages that have proved effective under the most severe trials, when in good order, have utterly failed when they have been neglected, or when the springs have been faulty.

The different varieties of safety-cages may be divided into five classes :—

- 1st. Those which have grippers acting on the sides of the skids or runners, and in which the weight of the cage keeps the grippers apart, whilst, if the rope breaks, they are made to grip the sides of the skids by means of springs.
- 2nd. Those where, on the rope breaking, two chisel-pointed grippers strike and enter the face of the skids.
- 3rd. Those that are furnished with arms that strike into the sides or ends of the shaft, and which, like the two former, are kept from acting by the weight of the cage, whilst, should the rope break, the arms are thrust out by springs.
- 4th. Those that have wedges or rollers acting on the sides of the skids or runners, and in which the weight of the falling cage forces the wedge or roller into contact with the skids, and so stops the cage should the rope break.
- 5th. Those that are independent of the weight of the cage and act by specific gravity.

The test usually given to safety-cages has been by severing the connection between the cage and the rope at the shackle immediately above the cage. But a more severe test should be applied, to allow for the influence that the backdrag of the rope between the winding-gear and the pulley-wheel would have, in case the rope should break at the winding-gear, somewhat as follows :—A clamp is fixed to the winding-rope, close to the drum, and, by means of chains, securely fastened to a bar or timber near the drum. The winding-rope is then slackened for several feet, and so placed that it can run freely. By means of a slip-hook, the clamped rope is then suddenly liberated, and the result is noted. This test should be made at the surface with an empty cage and an empty or full truck on, and at a convenient level at some distance below the surface, also with an empty cage and an empty or full truck on the cage. With this test it will be found that some cages will fail altogether, some will fail on the surface, but will act well a certain distance down the shaft (owing to the back-drag between the pulley and the drum being counterbalanced by the weight of the rope down the shaft).

In addition to the safety appliances brought into action when the rope breaks, several cages are fitted with a hand-lever, by which the cage can be stopped by the miners themselves whilst in the

*Safety Cages—continued.*

cage. In some cases the hand-lever is attached to the main safety appliances, whilst in others it is independent of them, and is an additional safety-appliance actuated by hand. This is a desirable adjunct to a safety-cage, and may be the means of saving life when the cage is being lowered into water, gas, or foul air. The hand appliance separate from the main safety appliance is preferable to that connected with it, both because it forms an additional holding power, and also because it takes up less room in the cage, whilst equally efficient.

The grippers, which form a very important part of safety appliances, are of many different shapes or designs, as (*a*) chisel-pointed and cutting into the runners, (*b*) with serrated or embossed sides that present considerable holding surface to the skids, (*c*) with several teeth that by an eccentric motion claw the runners, (*d*) a gripper on one side only, whilst an iron check-plate is fixed to the other side, the skid being firmly held between the gripper and check-plate when the appliance is in action. The chisel-pointed gripper is quickest in action and least liable to slip, and one gripper with a check-plate on the other side is in some cases preferable to a gripper on each side.

The shoes of the cage should fit the skids or runners, to admit of the grippers being set in their proper position. It is well to make the shoes large enough to enable steel liners to be fitted into them, which can easily be renewed when worn.

The springs upon which depend the action of the safety appliances are of numerous designs—(*a*) spiral, (*b*) flat and like a coach or buggy spring, (*c*) with a spiral band, (*d*) of rubber in a state of tension, (*e*) with a block of rubber compressed. Where one spring alone is used, the flat or coach spring gives very good results; but where four spiral springs acting directly one to each gripper are used, the results are equally good. Rubber springs in tension have not proved equal to steel springs. In some instances the springs are confined in a square case so that they are not visible; but where possible they should be exposed to view, so that their condition can be easily seen and readily tested. Where the winding is very rapid, there is a severe strain upon the springs, both from the shock of the cage coming to the bottom, and also from the sudden pull when the cage is lifted with a load, the work being too rapid to allow of its being done gently. As many as 800 cage loads are brought up in a shift of 8 hours, and from the consequent strain on the springs the latter have to be renewed very frequently. The springs should be sufficiently strong and in good order, and should be close up to the work, so that the safety appliances act instantaneously. It must, however, be borne in mind that if the springs be too finely set, the appliances are liable to act when not required, in quick winding or from the oscillation of the rope, which is a source of danger; and managers should be careful to ascertain that the springs are at the correct point of

*Safety Cages—continued.*

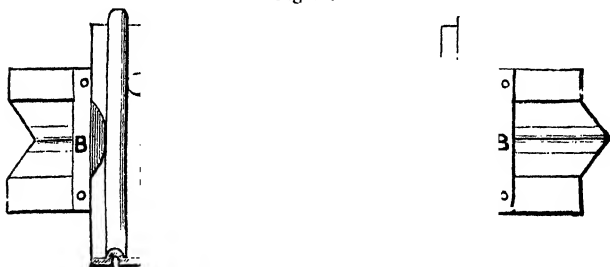
tension so that they will neither cause the cage to catch in the shaft nor fail to make the safety appliances act instantaneously in case of the rope breaking.

Safety-hooks, although not forming part of the safety-cages, are intimately connected with them. A great number of accidents have been averted by their use.

*Permanent Way.*

An improved system of chairs and sleepers has lately been brought out by the Chair and Sleeper Company (Limited), Widnes, Lancashire.\* In Fig. 11, A is a spring clip riveted to the sleeper,

Fig. 11.



Improved System of Chairs and Sleepers.

and is hammered round on to flange of rail to fasten it. Two of these spring clips are used for joint sleepers. B is a fixed clip, but for light pit rails a small spring clip is riveted to one side of the sleeper only. For ordinary tram rails, for which all the advantages of a fished joint without any of its disadvantages are claimed, a method is adopted in which the ordinary back-clip of the sleeper is widened and lengthened out till it assumes the dimensions of an ordinary fishplate. This is riveted to the sleeper, and has suitable studs projecting on it, which engage into the ordinary fishholes of the rail when it is placed on the sleeper. The steel spring clip, which is made of the best steel, and riveted to the sleeper on a washer, so that it can revolve, is then hammered round, until the end of it mounts the flange of the rail—one corner, only, of the clip being turned up, to give it a start on the flange. A great strain is thus put upon the clip, and it is somewhat lifted. This strain, combined with the elasticity of the steel, is so adjusted to the different sections of rails as to take up any wear there may be on the rail; thus always forming a tight fastening, and holding up the rail against the back fishplate, which thus takes all the outward thrust of the railway wheels. The steel revolving clips have

\* The same firm have many other improvements in rails, sleepers, and fastenings.

*Permanent Way—continued.*

square corners, which spring up against the web of the rail, and thus prevent them from turning round or working loose. By this means, it will be seen, the rails are not only fastened to each other, but also at the same time to the sleeper, a great advantage, especially on inclines. The saving is apparent when it is stated that nothing but a hammer is required to lay a railway by this system, and consequently any unskilled labour can be used.

*Aerial Wire Rope Tramways.*

Aerial wire rope lines are specially suited for mining purposes, and besides being used for the transporting of ore, coal, slag, &c., are now being adopted for the carriage for all kinds of goods where an ordinary railway cannot well be employed.

By means of these lines the steepest gradients can be surmounted, and rivers, buildings, &c., easily passed over. Loading and unloading can go on during all weathers, as the working of the line is not interfered with by rain or snow. Comparatively inexpensive foundations are required, and the number of men employed is reduced to a minimum.

Aerial lines cannot be worked satisfactorily round *curves*, care should therefore be taken when setting out one of these lines to have the loading and unloading stations so situated that the ropeway can be carried in a straight line from one to the other. If this is not possible, one or more so-called angle stations must be employed; these, however, increase the cost of working, and should be avoided unless absolutely necessary.

There are two systems of aerial lines, the single rope and the double rope.

The single rope lines have an endless running rope, which at the same time does duty for carrying and hauling the buckets. The buckets are either rigidly attached to the rope, or are suspended by means of a saddle which grips the rope by friction. These lines are cheaper and simpler than the double-rope ones, and are suitable for light loads and easy gradients.

The double rope or "Otto" system employs an independent heavy fixed rope for carrying, and a light running rope for hauling the buckets. The usual loads for the single lines are 2-3 cwt., for the double lines 5-8 cwt., in special cases, up to 10 and even 20 cwt. can be carried. The steepest gradients can be worked with safety by the double lines; the buckets are attached to the hauling rope by means of special grips, and travel at about 300 ft. per minute. The double lines are capable of transporting 60-80 tons of ore per hour, and of working over very long distances.

The supports are either of wood or iron, and are usually two-legged, four-legged supports only being employed at points where the strains are very great.

Spans up to 1500 ft. where necessary can be adopted; but such



*Aerial Tramways—continued.*

very large spans are not recommended, unless the section of the ground absolutely requires it. For fairly even country, the supports are generally placed 100–200 ft. apart, according to the quantity of material to be transported.

The following particulars of Otto's double rope system have been furnished by Commans & Co., 52, Gracechurch Street, London, E.C. :—

Ordinary wooden supports cost 45*l.* a piece; iron ones 8–10*l.*; high standards proportionately more.

The carrying ropes have usually a diameter of 1–1½ in. for the loaded rope, and  $\frac{3}{4}$ – $\frac{7}{8}$  in. for the unloaded; the hauling rope has a diameter of 3–3½ in., according to the length of line and the quantity that has to be transported. It is not advisable to make the section of a line more than 3–3½ miles long.

The power required for driving these ropeways is very small.

The cost of ropeways of course varies very considerably, according to the quantity of the material to be transported, and the nature of the country to be crossed. The ironwork for a line, including ropes, buckets, and terminal gear complete, but exclusive of supports and erection, would cost approximately 1000*l.*–1500*l.* per mile for the single rope system, and 1200*l.*–2000*l.* per mile, for the double rope system, according to the quantity carried.

The cost of erection depends so much on the part of the world in which the line is to be employed, and the cost there of labour and material, that it is impossible to give anything like a reliable figure for this.

The subjoined particulars, furnished by Bullivant & Co., 72, Mark Lane, London, E.C., will enable the reader to form an idea of the cost of any tramway he may contemplate erecting, but as the price varies greatly according to the ground passed over and the material to be transported, it must be borne in mind that the amounts given are purely approximate.

	50 Ton per 10 hours Line.	100 Ton per 10 hours Line.	200 Ton per 10 hours Line.
	£	£	£
1. Rope, pulleys, and rolling stock for a length not exceeding one mile . . . . .	310	460	580
2. Driving and tightening gears with shunt rails for a tramway, one mile or less in length . . . . .	60	130	170
3. Rope, pulleys, and rolling stock for a length not exceeding 3 miles, but over one mile, per mile . . . . .	340	490	620
4. Driving and tightening gears with shunt rails for a tramway not exceeding 3 miles in length, but over one mile . . . . .	120	250	300
5. Angles, giving any degree of deviation . . . . . each	25	35	45
6. Packing, &c. . . . . about	20 to 30	30 to 40	40 to 50

*Aerial Tramways—continued.*

To which must be added the cost of wood posts, and engine power. The former average about 30 per mile, and on level ground are about 15 ft. high, costing 4*l.* to 5*l.* each—irregularities of level will cause a corresponding variation in the heights of the posts.

The amount of engine power varies under all circumstances.

The wood frames for carrying terminal gears and shunts rails are not included in above prices.

The prices above will usually be found to be rather in excess of a final estimate made on receipt of full particulars.

Tramways for lengths under half a mile should be specially estimated for.

To illustrate the proper method of estimating from above prices, the following examples are given, viz. :—

1. Cost required for a tramway  $\frac{3}{4}$  mile long to carry 50 tons per 10 hours with one angle.

Rope, pulleys, and rolling stock as per No. 1, 310*l.* per mile, or for  $\frac{3}{4}$  mile 232*l.* 10*s.*, and terminal gear, &c., as per No. 3, 60*l.*, and with curve as per No. 5, 25*l.* Total cost, 317*l.* 10*s.*

2. Cost required of a tramway 2 miles long to carry 100 tons per 10 hours as per No. 2.

Rope, pulleys and rolling stock will cost 980*l.*, and, as per No. 4, driving gear, &c., will cost 250*l.* Total 1230*l.*

Packing is only necessary for export.

## WATER SOFTENING.

Water is generally described as being soft or hard. It is called hard when it contains considerable quantities of the salts of calcium and magnesium in solution, but when only a small quantity of these salts is present it is called soft. The chlorides, sulphates, and nitrates of calcium and magnesium are easily dissolved and maintained in solution by water, but the carbonates of these elements can only be maintained in solution by an excess of carbonic acid in the form of bi-carbonates.

The following distinctions are made with regard to hard waters:—

- (1) Temporary hardness, that is, hardness caused by the bi-carbonates of the alkaline earths, and which disappears in boiling.
- (2) Permanent hardness, that is, hardness caused by the chlorides, sulphates, and nitrates of the alkaline earths, which is not lessened by boiling. The sum of the temporary and permanent hardness is the total or aggregate hardness.

In order to express the relative hardness of different waters, the following measurements have been adopted:—

England ..	1 grain of calcium carbonate ( $\text{CaCO}_3$ ) per gallon of water.
France ..	10 milligrams of calcium carbonate ( $\text{CaCO}_3$ ) per litre of water.
Germany ..	10 milligrams of calcium oxide ( $\text{CaO}$ ) per litre water.

Calcium, in the form of bi-carbonates and sulphates, is the chief constituent of the dissolved mineral matter in hard water, whilst it occurs also in small quantities as chlorides, nitrates, and nitrites. Next in order comes magnesium in the same combination as calcium. The bi-carbonates of iron and manganese, and the carbonates, chlorides, sulphates, nitrates, and silicates of sodium and potassium, are rarely absent, but seldom occur in large quantities. Water also absorbs oxygen, nitrogen, and carbonic acid, and occasionally sulphuretted hydrogen may be found in it. Organic matter occurs in some lake and river waters. Carbonic acid enables water to dissolve substances, such as the carbonates of calcium, magnesium, iron, and manganese (which pure water could only dissolve with great difficulty in minute quantities if at all), by converting the carbonates into bi-carbonates, the bi-carbonates

*Water Softening—continued.*

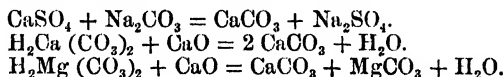
being soluble in pure water. It has been found from experience that scale over the heating surfaces of a boiler to the thickness of  $\frac{1}{16}$  in. will cause a waste of about an eighth of the efficiency of the boiler, and the waste increases as the square of the thickness. The amount of incrustation varies considerably with the quality of water, and with the regularity with which the operations of blowing through and cleaning out are practised. Occasionally vegetable matter of a glutinous nature, held in suspension by the feed water and precipitated by heat or concentration, covers the heating surface with a thin coating almost impermeable to heat, and which hardens the mineral deposit so that it is next to impossible to remove it, and hence causes overheating.

The Porter-Clark process is based on the following theory:—When ordinary burnt lime or calcium oxide is added to water which contains the bi-carbonates of lime or manganese, the excess of carbonic acid necessary to keep the lime or magnesia in solution in the form of a bi-carbonate combines with the calcium oxide, forming insoluble carbonate of lime, both by the decomposition of the bi-carbonate of lime and by the combination of the excess of carbonic acid given off in decomposition with calcium oxide added to the water.

In this reaction the carbonates only are precipitated. The sulphates are precipitated by using a small quantity of soda,  $\text{Na}_2\text{CO}_3$ . The sodium carbonate and calcium sulphate mutually exchange their acids, forming insoluble carbonate of lime and soluble sulphate of soda. The latter salt is so very soluble that it is not precipitated even after much concentration upon evaporation, and thus it flows out of the boiler when the mud-plugs are removed for washing-out.

A little alum is mixed with the soda to aid the precipitation of solid matter held in suspension by the water; it also materially assists the precipitation of the salts in the precipitating tanks.

The reaction is represented by the following equations:—



The quantity of lime required to soften 1000 gal. of water is 2·24 lb.; soda, 4·5 lb.; and alum, 0·1 lb. The above quantities give very satisfactory results. It is not found necessary to reduce the degree of hardness lower than 6° and 7°, as the heating surfaces are kept practically clean when water of this degree of hardness is used. The water, after being softened, dislodges old incrustations and deposits from boilers previously using hard water. (W. W. F. Pullen, Proc. Inst. C.E., xcvi. 354.)

## STAMP BATTERIES.

STAMP BATTERIES: *Gold.*

To find the horse-power required to drive a battery, multiply the weight of one stamp by the number of stamps in the battery by the height of lift in ft. by the number of lifts per minute; add one-third of the product to the result for friction, which will be the number of ft.-lb. per minute; divide this by 33,000, which is the number of ft.-lb. per minute equal to 1 H.P., and the result will be the H.P. required. For example, supposing a stamp weighs 800 lb., that there are 5 in a set, that each stamp has a lift of 9 in. = 0.75 ft., and gives 80 blows per minute, then:— $800 \times 5 \times 0.75 \times 80 = 240,000$ ; one-third of 240,000 = 80,000; this added to 240,000 = 320,000: 320,000 divided by 33,000 = 9.7 H.P., or 1.9 H.P. per stamp. The total weight of a battery, including mortar-box, stampers, &c., may be roughly estimated at 1 ton per stamp. Medium-sized stampers, i. e. stem, tappet, head, and shoe, weigh 600–700 lb., and require about  $\frac{1}{2}$  H.P. Heavy stampers weigh 800 lb. and over.

Table 89.—*Dimensions of Parts of Stamps.*

Name of Mill.	Length of Stem.	1 diam. of Stem.	Weight of Stem	Height of Shoe.	Diam. of Shoe	Weight of Shoe.	Height of Boss.
	ft.	in.	lb.	in.	in.	lb.	in.
Douglas .. .. .	12 $\frac{1}{2}$	2 $\frac{1}{8}$	290	9	8	115	18
Cons., Virginia ..	13	3 $\frac{1}{8}$	320	7	8	110	16
Lincoln .. .. .	13	3 $\frac{1}{8}$	320	7	8 $\frac{1}{2}$	119	18
Brunswick .. ..	15	3 $\frac{1}{8}$	375	10	9	125	18
Electric .. .. .	11 $\frac{3}{8}$	3	258	8	8 $\frac{1}{2}$	123	16
Eureka .. .. .	14	3 $\frac{1}{2}$	450	..	..	160	..
Keystone .. .. .	..	..	..	..	..	100	..
Stanford .. .. .	..	..	..	..	..	120	..
Walhalla .. .. .	10 $\frac{1}{2}$	3 $\frac{3}{8}$	..	9	10	..	14

Name of Mill.	Diam. of Boss.	Height of Tappet.	Diam. of Tappet.	Weight of Tappet.	Height of Die.	Diam. of Die.	Weight of Die.
	in.	in.	in.	lb.	in.	in.	lb.
Douglas .. .. .	8	12	8	120	..	..	..
Cons., Virginia ..	8	10	7 $\frac{1}{2}$	95	..	..	..
Lincoln .. .. .	8 $\frac{1}{2}$	10	7 $\frac{1}{2}$	93	5 $\frac{1}{2}$	8 $\frac{1}{2}$	99
Brunswick .. ..	8	12	9	125	..	..	..
Electric .. .. .	8 $\frac{1}{8}$	8 $\frac{1}{2}$	7 $\frac{1}{2}$	83	6	8 $\frac{1}{8}$	100
Eureka .. .. .	..	..	..	120	..	..	120
Keystone .. .. .	..	..	..	100	..	..	113
Stanford .. .. .	..	..	..	114	..	..	..
Walhalla .. .. .	10	..	..	..	..	..	..

Table 90.—*Dimensions and Working Results of a number of Mills in various parts of the World.*

Mill or District.	Weight of Stamps.	Drops per Minute.	Depth of Drop.	Crushed per 24 Hours.	No. of Stamps.	Duty per Stamp.	H.P. per Stamp.	Holes per sq. in. of Grating.	Water per Stamp per 24 Hours.	Mercury used per Stamp.	Mercury lost per Stamp.
	lb.		in.	tons		tons			gal.	lb.	oz.
Grass Valley..	850	61	10	40	20	2	..	..	..	..	..
"	700	63	10	32	20	1-12	..	..	..	..	..
Enreka ..	950	80	9	..	60	2-3	..	..	..	..	..
Brunswick	..	..	..	160	56	3	..	..	..	..	..
Keystone	750	75-80	..	75-80	40	2	..	..	..	..	..
Idaho ..	950	80	9	..	..	..	..	..	..	..	..
Metacom	900	90	10	..	..	..	..	..	..	..	..
Port Philip	672	75	..	..	56	2-2	1	..	..	..	..
"	896	75	..	..	24	3	1-1	..	..	..	..
Nova Scotia ..	650	55	6-9	..	..	1-1-1	..	..	..	..	..
	cwt.										
Ballarat ..	4-8-1	50-85	7-10	..	..	1-4	1-2	40-200	950-8,640	5-75	1-8
Beechworth	4-4-7-1	40-90	5-14	..	..	1-4	1-1	60-140	720-11,520	5-70	1-8
Sandhurst	5-8	25-75	6-18	..	..	1-3-1	1-2	64-140	4,000-8,640	10-40	1-5-1
Maryborough	4-8	50-75	6-22	..	..	1-3	1-2	70-144	1,000-8,640	3-30	1-8
Castlemaine ..	4-1-8	35-75	6-15	..	..	1-3-1	1-2	40-144	4,800-12,960	6-40	1-2-1
Ararat ..	5-6-1	60-72	7-10	..	..	1-1-1	1	90-120	4,320-12,960	6-47	1-7
Gippsland ..	6-1-1	60-80	7-10	..	..	1-1-2	1-1	70-250	1,600-25,000	10-37	1-32

*Gold Batteries—continued.*

*Life of Battery.*—The duration of the several parts of a stamp battery is very unequal. An ordinary die should last about twice as long as the shoe, or say six weeks to two months; the rate of wear is commonly  $\frac{1}{2}$ –1 lb. per ton of ore treated. The conditions which govern the rate of wear are the speed of the battery, regularity of feeding, hardness of ore, and quality of iron. Good cast iron is as enduring as steel, but much of the cast iron employed for this purpose in remote localities is far from good. Shoes generally last 4–6 weeks, wearing at the rate of  $\frac{1}{2}$ –1 $\frac{1}{2}$  lb. per ton of ore put through.

Stamp stems, especially when running in wooden guides, should last 3 or 4 years, and, with regular feeding, very much longer; the jar occasioned by a short supply of ore in the mortar is apt to cause them to break off at the ends. When this happens, the injury is remedied by welding on a piece, which may be done repeatedly. Stamp heads sometimes split when not bound with iron rings, and the sockets become enlarged by wear; but the latter drawback may be overcome by inserting wooden or iron wedges. Tappets should endure 4 or 5 years, but are sometimes split through wedging up too tightly.

Table 91.—*Gauges of Screens.*

No. of Needle.	Mesh.	Width of Slot.
1	12	$\frac{58}{1000}$ in.
2	14	$\frac{49}{1000}$
3	16	$\frac{42}{1000}$
4	18	$\frac{35}{1000}$
5	20	$\frac{29}{1000}$
6	25	$\frac{27}{1000}$
7	30	$\frac{24}{1000}$
8	35	$\frac{22}{1000}$
9	40	$\frac{20}{1000}$
10	50	$\frac{18}{1000}$
11	55	$\frac{33}{2000}$
12	60	$\frac{18}{1000}$

## CRUSHING ROLLS.

Table 92.—CRUSHING ROLLS: Dimensions and Product at various Mines.

Name of Mine.	Rolls.			Total		Sifter.		Dia- meter of Ruff- Wheel.	Horse- power.	Quantity Crushed in 10 Hours.	Cost of Crushing per ton.
	Dia- meter.	Length.	Revo- lutions per Minute.	Crushing Area per Minute.	Pressure on Rolls.	Length.	No. of Holes.				
Grassington Mines..	in.	in.		sq. in.	cwt.	in.	sq. in.	ft.	tons.	d.	
Minera ..	27	12	5 $\frac{1}{2}$	5,593	91	21	6 $\frac{1}{2}$	14	80	21	
Cwmystwith, No. 1 ..	14	14	8	4,920	73 $\frac{1}{2}$	24	9	48	20	21	
Cwmystwith, No. 2 ..	27	14	4	4,748	78	20	9	24	32	21	
Goginan ..	27	14	4 $\frac{1}{2}$	5,341	85	24	9	24	35	21	
Cwm Erfn ..	30	14	5 $\frac{1}{2}$	7,254	39	20	9	36	30	24	
Lisburne, No. 1 ..	27	14	7 $\frac{1}{2}$	8,902	293	26	9	30	20	3	
Lisburne, No. 2 ..	27	15	6	7,632	180	22	12 $\frac{1}{2}$	30	42	21	
Derwent ..	27	14	7	8,309	227	22	16	30	42	21	
Goldscope ..	14	18	14	11,060	6	..	..	15	60	21	
East Darren ..	30	18	6	9,996	207	24	16	45	25	21	
Cefn Cwm Brwyno ..	20	13	5	4,080	84	20	16	27 $\frac{1}{2}$	20	21	
Lisburne, No. 3 ..	18	16	8	6,432	169	22	25	30	42	21	
Llandudno ..	18	15	15	12,705	61	..	..	..	30	..	
Wheal Friendship..	23	12	10	8,670	123	24	36	30	13	11	
Pontigbaud ..	25	12	12 $\frac{1}{2}$	12,075	36	22	44	60	15	17	
Devon Great Consols ..	34	22	7	16,433	458	24	64	21	65	31	



*Jordan's Patent "Centrifugal" Process.*

One set of plant comprising this process consists of the following:—

- One ordinary "Blake" stone-breaker.  
 „ Jordan's patent fine reducer.  
 „ „ „ amalgamator.

This set is equal in capacity to 10 heads of Californian gravitation stamps, if placed on the same basis as to nature of quartz and fineness of grinding.

The process is complete in itself, the amalgamator taking the place of copper table, pan amalgamators, blanket strakes, and all other appliances. It is capable of treating the most refractory ores and of saving 85 to 95 per cent. of the gold contained, whilst practically the whole of the precious metal is extracted from free-milling ores.

The amalgamators are also often used in front of ordinary stamp batteries, especially where fine or float gold is concerned, which they are found very efficacious in catching.

The following table of comparisons between the process and the ordinary stamp battery will probably be useful:—

*A. Jordan's Potent Plant.    B. Stamp Battery.*

	Cost of Plant.	Weight of Plant.	Freight at £15 per ton.	Cost of Erection on a moderate site.	Time occupied in Erection.
A	£800	15 tons.	£225	£50	2 to 3 weeks.
B	£1,399	51½ tons.	£772	say £275	2 to 3 months.
	Power required to Drive Plant.	Cost for Treatment per ton of Ore.	Cost of complete Plant Erected, say, in Transvaal, without Power.	Labour for Double Shift.	Cost of Wear and Tear and Renewals per annum.
A	8 to 10 H.P.	5s. to 10s.	£1,075	2 skilled mechanics, 2 labourers.	£50
B	15 to 20 H.P.	12s. to 18s.	£2,416	4 skilled mechanics, 6 labourers.	£150 to £200

Table 93.—*Cost of Jordan's Centrifugal Plant.*

	£
One patent stone-breaker .. .. .	100
" " centrifugal fine reducer .. .. .	250
" " " amalgamator .. .. .	250
The necessary shafting, pulleys, bearings, couplings, gear, belting, and laces for driving, and the necessary pipes, cocks, and connections for the immediate water supply .. .. .	200
One set complete ready for working .. .. .	800
A suitable steam engine for driving one set of the plant of high pressure horizontal type, having cylinder 10 in. diam. and 18 in. stroke, feed pump and high speed governor and throttle valve complete. The engine of high-class workmanship and very best material .. .. .	154
A single-flued multitubular steel boiler 11 ft. long by 5 ft. diam., with all the necessary mountings, and fitted with smoke-box jacketed to act as feed-water heater, and 20 ft. wrought iron chimney 2 ft. diam. The whole arranged so as to require no brick setting or flues .. .. .	255
Steam and blow-off pipes, cocks and connections between engine and boiler, supposing the same to be in close proximity .. .. .	20
Engine and boiler complete as above .. .. .	429
Process complete with engine and boiler and all accessories as above .. .. .	1229

From 5 to 10 per cent. should be added to the above prices for packing for shipment, and delivery F.O.B. English port.

## RIVER MINING.

RIVER MINING: *Ball Dredger.* (Langley.)

The fan makes 350 revolutions per minute, and at that speed is capable of raising 400 tons of sand, gravel, and stones per hour, but the average in actual work may be taken at 200 tons per hour. This is with a 10 h.p. engine, and working in a depth of water varying from 7 to 25 ft.

Table 94.—*Cost of Dredging.*

Cost of dredger, say .. .. .	2000 <i>l.</i>
Nominal horse-power .. .. .	10 H.P.
Depth at which it excavates .. .. .	25 ft.
Quantity it excavates per annum .. .. .	200,000 tons.
<hr/>	
Labour for dredging, lead (2 miles) and discharging .. per ton	2·125 <i>d.</i>
Coal and other stores .. .. .	0·375 <i>d.</i>
Repairs (total £60) .. .. .	0·072 <i>d.</i>
<hr/>	
Total working cost .. .. .	2·572 <i>d.</i>
Add 10 per cent. interest on capital .. .. .	0·240 <i>d.</i>
<hr/>	
Total cost per ton, including interest on capital ..	2·812 <i>d.</i>
<hr/>	

This cost may be taken to be about 1½*d.* for dredging, and the balance for the towage of lighters and discharging at sea.

The consumption of coal is about 1 ton per 1000 tons of sand dredged.

## ORE DRESSING.

ORE DRESSING : *Conditions.*

The object of dressing ores is to separate the useful from the useless portions, and to sort the valuable minerals from each other. It should be carried out as near the mine as possible, to avoid carriage of worthless material. Water is essential, and the floors should be arranged so that the matters can be moved forward in a measure by their own specific gravity.

The specific gravity of minerals commonly met with in wet dressing floors is as follows :—

Mercury .. .. .	10·6	Barytes .. .. .	4·3-4·7
Silver .. .. .	10·5	Copper pyrites .. .. .	4·1-4·3
Copper .. .. .	8·4-9	Zincblende .. .. .	4·1
Iron .. .. .	7·5	Chalybite .. .. .	3·6-3·9
Galena .. .. .	7·5	Calamine .. .. .	3·3-3·6
Cassiterite .. .. .	6·4-7·1	Fluorspar .. .. .	3·1
Cinnabar .. .. .	6·7-8·2	Calcite .. .. .	2·6-3·0
Mispickel .. .. .	6·0-6·2	Felspar .. .. .	2·5-2·9
Proustite .. .. .	5·5	Quartz .. .. .	2·5-2·7
Iron pyrites .. .. .	4·8-5·2	Gypsum .. .. .	2·2-2·4
Fahlerz .. .. .	5·0-5·1	Coal .. .. .	1·2-1·5
Purple copper ore .. .. .	4·9-5·1	Lignite .. .. .	1·2-1·4
Magnetite .. .. .	4·8-5·2		

Decomposed silver and other ores are difficult to dress, especially if easily powdered, *e.g.* malachite, argentiferous cerussite, cinnabar, and spangles of native silver. It is difficult to separate zincblende, copper pyrites, iron pyrites, mispickel, and barytes from silver ores; wolfram from tin ores; chlorite and epidote from copper ores; and chalybite from copper pyrites and galena.

The following minerals are affected by the association of those in brackets :—

Hæmatite, limonite, and chalybite (iron and copper pyrites and apatite are injurious).

Cassiterite (iron pyrites, copper pyrites, mispickel, and zincblende are injurious; bismuth makes the colour dull; copper makes it brittle).

Lead (arsenic makes it brittle; antimony makes it hard; fluor-spar promotes its fusibility; chalybite and barytes are also advantageous).

Zinc (lead spoils it).

Copper (lead must be separated from it if it is to be treated by precipitation process).

*Conditions—continued.*

Silver (lead and antimony are injurious for the amalgamation process; also talc for chlorination).

Cobalt (for blue paint calcspar, brown spar, manganese spar, hornstone, ferruginous quartz, and galena are injurious; nickel, when predominant, imparts a red tinge; arsenic intensifies the blue colour, and renders it more agreeable).

Magnetite (mica, lime, garnet, augite, and hornblende promote its fusibility).

Auriferous pyrites (for chlorination process, talc is injurious).

When pieces of different minerals of the same size are allowed to settle in water, the heavier particles fall first. When pieces of different minerals of the same weight are subjected to a flow of water sufficient to move them along, the specific lighter material, having a larger surface exposed, is washed away quickest.

Another condition, not less important than those just given, for good concentration of the different classified portions of material, is the proper regulation of the velocity of the throw. For the tables applied to the treatment of the two coarser sizes, it ought, in the average, not to exceed 1 ft. per second, whilst slime-tables require a velocity of stroke of only 0.5 ft. per second; a greater velocity causes the tables to slide, so to speak, from underneath the particles of ore, thus retarding their progress. The motive power required for working a double table is 0.26 h.p., and the working effect per hour of a single table is 55 lb. of slimes and 300 lb. of sands. Six continuously-acting double tables are capable of working in 24 hours 10–12½ tons of crushed material, classified by four pyramidal boxes. These figures refer only to Rittinger's tables.



*Jigging.* (H. S. Munroe.)

It is hardly necessary to dwell upon the importance of the jig. Within its proper sphere no substitute has been found that does the work as well or as cheaply. Its capacity is large, it requires but little attention, and the losses are small. In one form or another, it is the principle machine used in the concentration of low-grade ores, and for the separation of one metallic mineral from another; and it is almost the only machine used for the purification of coal. There are two recognised systems of jigging, the English and the Continental or German. The English system is a development of the hand-jigging formerly employed in Cornwall and other metalliferous districts of England. In this method the crushed ore, coarse and fine together, is first jigged on a hand-sieve with coarse mesh; and the fine stuff, somewhat concentrated by passing through the bed of coarse mineral grains on the sieve, is again jigged on a sieve of finer mesh. In the adaptation of the system to machine-jigging, many modifications of detail have been necessary. The general treatment, however, is the same, and includes a preliminary jigging on roughing-jigs, followed by a concentration of the hutchwork on finishing-jigs of finer mesh. In both roughing- and finishing-jigs, a bed of mineral is maintained on the sieve; and the concentration is mainly effected by jigging through this bed. The Continental or German system starts with a size-classification by screens, after which the different sizes are treated on separate jigs.

There are also combinations of the two systems. The use of a bed of mineral grains, and concentration by jigging through the sieve, has been adopted in Continental practice for fine jigging. At the Lake Superior dressing-works, a somewhat imperfect size-classification by water has been introduced as a preliminary to jigging. In the Continental dressing-works, again, the tendency of late years has been to reduce the number of sizes jigged, and to abandon the very close sizing which formerly characterised the method.

The arguments for close sizing are drawn from the well-known laws governing the fall of bodies in water, which may be stated as follows:—A body falling in still water moves at first with accelerated velocity, as in a vacuum. The resistance of the water, however, increases with the square of the velocity, and finally equalises and neutralises the accelerating force. Thereafter the grains move with uniform falling velocity.

It is argued that, in order to effect a separation by the water-currents of a jig, the range of size in the grains treated must not exceed the size-ratio of equal-falling grains. But the conditions which obtain in jigging are not the same as in the case of bodies falling freely in water. We have to deal not with single isolated grains, but with numbers of these grains moving together. The

*Jigging—continued.*

smaller grains move in the interspaces between the large grains, and, consequently, in constricted channels. The large grains, also, so far as their movements are independent of the surrounding grains, as in the separation of gangue from ore, and of one mineral from another, move in the interstitial channels between the other grains. These channels must have great influence on the movement of the grains. Nevertheless many have been content to assume the formula for free-falling grains as of universal application, and have drawn therefrom the arguments and data for the close and accurate sizing characterising the Continental system of ore-dressing. It is, however, possible to effect a very satisfactory separation on jigs, with material sized between wide limits only, and in a very imperfect manner, or even entirely without sizing.

The principal advantage of the English method of jigging is that it dispenses with the operation of sizing by screens. The plant is thus simpler and cheaper, and the expense of treatment less. If the jigging be conducted entirely without size-classification, it has the further advantage that very fine material can be treated successfully on jigs, which would otherwise have to be treated on tables. The bulk of the gangue, both fine and coarse, is thus at once separated by the "roughing-jigs," leaving but a small amount of rich stuff to be treated on the finishing-jigs and tables. As the treatment of the fine stuff by itself is troublesome, and the capacity of slime-jigs and tables is small, the plant and method of treatment are still further simplified and cheapened.

The English method is especially well suited to the concentration of low-grade ores on a large scale.

The principal objection in practice to the English system of jigging is the imperfect concentration of the material passing through the jig-bed. The hutchwork is much richer when the stuff is sized before jigging. This difficulty is overcome by the re-treatment of this hutchwork on finishing-jigs. At Bonne Terre, the hutchwork is classified in pointed boxes, the sands re-treated on jigs, and the slimes concentrated on side-bump table.

Munroe's investigations suggest means whereby the hutchwork can be enriched without the necessity for this second treatment. By treatment of fine and coarse material together on the same jig, interstitial channels will be formed between the coarse grains, in which the fine stuff can be very perfectly concentrated. Again, by decreasing the mesh of the jig-sieve, the size of the interstitial channels may be reduced, and still finer material successfully concentrated. Experiments made to test the possibility of reducing the number of grades of sand, developed the unexpected result that the hutchwork was much improved by jigging coarse and fine stuff together, the reason for which is now clear. So also at Bonne Terre, where, however, the problem is complicated by the necessity of running the roughing-jigs so as to suck as much fine stuff through the sieve as possible.



*Jigging*—continued.

The problem to be solved in connection with the English method of jigging is to determine the best method of treating the stuff too fine to be concentrated successfully in the interstitial channels of the jig-bed.

The first and most obvious method is to separate the fine stuff by water-classification before jigging the sands. The objections to this course, are, first, the quantity of water required to effect the separation of the slime; and second, the fact that much fine stuff will be sent to the tables that could be treated successfully on the jigs.

A second plan is to separate the fine stuff from the tailings of the jigs by proper classifiers. This is perfectly feasible, and has the advantage that the jigs can be so run as to produce a rich hutchwork. This plan requires large settling-tanks, and a considerable amount of clean water to effect the separation of the slime. It has the advantage over the plan of separating before jigging that the fine mineral is partly concentrated and saved by the jigs.

A third plan, which will effect a partial solution of the problem, is to run the jigs so as to take full advantage of the interstitial action. By reducing the mesh of the jig-sieve, finer material can be concentrated. With a given maximum size for the coarse sand-grains, however, a limit will be found beyond which the mesh of the sieve cannot be reduced. Possibly it may be found practicable to use a three or four-sieved jig, with different mesh on each sieve, and, by varying the stroke of the pistons, to adapt each sieve to the saving of a certain grade of sand. At Lake Superior the tail-sieves have finer mesh than the head-sieves. Or the roughing-jigs may be run with little under-water, so as to suck all, or nearly all, of the fine stuff through, thus ensuring poor tailings, and the hutchwork may then be treated again on jigs of finer mesh. These finer jigs should be run in the same way, and their hutchwork should be treated on tables.

By one or another of the above methods, it may be found practicable to save and treat the slime without using classifiers to separate it from the sands.

A fourth plan is to conduct the crushing so as to produce a minimum amount of slime; for example, by a system of gradual crushing, using two or more sets of rolls; or by coarse-crushing, followed by jigging and fine-crushing of "raggings" only; or, again, by calcining the ore so as to make it more friable. By one or another of these methods it may be possible to limit the production of fine stuff, so that in many cases it may be allowed to escape without serious loss.

The following are the main points developed by Munroe's investigations:—

1. Bodies falling through water in a tube do not attain as high a velocity as in falling through the same medium in large vessels.

*Jigging*—continued.

2. The falling velocity is but little affected when the diameter of the body is less than  $\frac{1}{10}$  that of the tube.

3. The falling velocity is the more retarded as the diameter of the body approximates that of the tube.

4. A sphere  $\frac{4}{10}$  the size of the tube will develop the greatest falling velocity, and will require a current of maximum velocity to support or raise it.

5. Grains falling *en masse* are really moving in confined channels, and follow the law of the movement of bodies in tubes. The falling velocity, and the velocity of the current necessary to support or raise the mass of grains, increase and diminish with the distance apart of the grains.

6. The diameter of the channel in which the single grain moves equals the cube root of the volume of the grain with its proportion of the interstitial space, or, in other words, the cube root of the space occupied by the grain.

7. In a mass of grains of different sizes, the large grains move relatively in smaller channels than the small grains. The ratio of the diameters of equal-falling grains of quartz and galena, under such conditions, is 31 to 1, instead of 4 to 1, which latter ratio holds good for free-falling grains only.

8. The formulæ for grains moving in tubes, when applied as above to grains moving *en masse*, enable us to compute the velocity of jig-currents and thus determine the proper length and number of strokes of the jig-piston. The old formulæ gave results many times too large.

9. Close sizing is not necessary for the separation of different minerals by jigging, unless the difference in specific gravity is small.

10. Downward currents are apparently necessary to success in jigging through a bed. This requires confirmation by experiments on a larger scale.

11. Very fine material, less than  $\frac{1}{10}$  millimeter diam., can be treated successfully on jigs, if treated with coarse stuff, the concentration taking place in the small interstitial channels between the grains forming the mineral bed. For the treatment of fine stuff on jigs, close sizing is a positive disadvantage. Jigs work well on mixed stuff, and very badly on fine stuff alone. Stuff less than  $\frac{4}{10}$  the size of the smallest interstitial channels cannot be treated successfully in this way.

12. The size of the mesh of the jig-sieve has a very important influence, and must be proportioned to the work to be done.

## GOLD.

## SLUICES.

Sluices must vary in length according to the nature of the dirt being washed, and must be determined in each instance by actual experiment, an increase being necessary if assays of the tailings show a loss of gold. The sluice is generally run on a wide curve, the outside edge being raised  $\frac{1}{2}$ -1 in. to equalise the wear and tear, because in a straight sluice the velocity of the current would be likely to carry away much of the dirt without disintegrating it. The dimensions of the sluice are determined by the quantity of material to be treated, which is governed by the water supply. One 6 ft. wide by 3 ft. deep, with a 4-5 per cent. grade, will take about 3500 miners' "inches"; one 4 ft. wide by  $2\frac{1}{2}$  ft. deep, with  $2\frac{1}{2}$  per cent. grade, 1200-1500; or with 4 per cent. grade, 2000 miners' "inches." The water must be in sufficient depth to cover the largest boulder likely to be encountered, so that the body required will vary with the coarseness or fineness of the dirt. With too much water, the riffles are likely to pack, and the yield of gold will be less, increasing with low grade and small body of water. If water is plentiful and cheap, it will to a certain extent atone for low grade; but with water scarce and dear, a high grade is essential.

GOLD SLUICING: *Water consumed.*

Generally speaking, ordinary gravel needs 4 per cent., and coarse gravel 6-7 per cent.: the heavier the gravel the steeper the grade, and the more water necessary; 4 per cent. is very commonly used, increased to 6 and even 8 for clay, and reduced sometimes to  $1\frac{1}{2}$  per cent. for very light dirt. The "No. 8" mine of the North Bloomfield Gravel-Mining Co. required an average of 534 cub. ft. of water to wash 1 cub. yd. of gravel; or, in other words, the gravel at this locality required for moving it an expenditure of water nearly equal to 20 times its bulk. At the Blue Tent Co.'s mine, where careful record has been kept of the amount of gravel washed, water used, &c., for the past few years, the various kinds of gravel met with were moved at the rate of from 2.38 to 10.12 cub. yd. per miners' "24-hour inch" (which is considered on the San Juan divide equal to 2230 cub. ft. of water; in the Bear River mines, about 2200),

*Gold Sluicing—continued.*

or, in other words, the gravel required, according to its condition, from 8 to 34 times its volume of water to disintegrate it and carry it into the sluices. Hague adopted 7 cub. yd. as the amount of gravel which, on the average, in the divide between the South and the Middle Yuba, could be moved by a "24-hour inch" of water, and this is said by Prof. Pettee to be corroborated by the results obtained at Smartsville; 7 cub. yd. to the "24-hour inch" gives an amount of gravel not quite  $\frac{1}{12}$  of the volume of the water used. Ashburner considered that a "24-hour inch" of water would move only about  $3\frac{1}{2}$  cub. yd. of the lower portion of the gravel deposit in Bear River and its tributaries. This gravel may be considered as representing the hardest kind ordinarily worked by the hydraulic method. It appears, therefore, that a "24-hour inch" of water will disintegrate and carry into the sluices 2-10 cub. yd. of gravel, according to the character of the material.

*GOLD SLUICING: Utilising current of large rivers. (Thomson).*

A screw 8 ft. diameter will give 8 H.P., and can be immersed and attached to any fixture. It will raise one Otago sluice head of water (equal to 95 cub. ft. of water delivered per minute) to an elevation of 70 ft., or 7 heads 10 ft., without intermission. The screw may be made of timber, and can be put together by any blacksmith or carpenter. Minor scientific faults in its form are compensated by an excess of current-power. The accessories requiring skill in their construction are a brass force-pump and some rubber tubing. With a screw or fan 15 in. diameter, with blades set at an angle of  $20^\circ$  to the disc, in a 2-mile current, the revolutions are nearly 1 per second; the pistons of the pump are worked by a crank, propelling the contents once per second; the diameter of the cylinder is  $\frac{3}{4}$  in.; stroke of piston, 2.7 in.; quantity of water per stroke, 1.1925 cub. in., or 71.55 cub. in. per minute, or 59.5 cub. ft. or 368.9 gal. per 24 hours; cost 4*l.* or 5*l.* The capacity and cost increase, of course, with the size. The whole apparatus is easily repaired, and can be removed at will.

*GOLD SLUICING: Cost.*

Under favourable conditions for hydraulic washing two men can do all the work in a washing that uses 300 miners' "inches" of water. Under such circumstances, 1 pipe will break down as much as 3 can wash away; on the other hand, 3 pipes are sometimes required to break down what 1 can wash away. The water is generally considered capable of carrying away  $\frac{1}{3}$  of its own weight of gravel.

Table 96.—Average cost for the La Grange Company. (Bowie).

Per oz. of Metal produced.				Per cub. yd. treated.			
		s.	d.			s.	d.
Water	..	..	5 10	Water	..	..	0 4
Labour	..	..	28 4	Labour	..	..	1 8
Material	..	..	7 6	Material	..	..	0 5
Officers	..	..	3 11	Officers and conti-)			
Contingent expenses			1 1	gent expenses	..	}	0 3
Taxes	..	..	0 4				
			<hr/> 47 0				

With light pressure and low grade.

Table 97.—With heavy pressure and low grade.

For heavy pressure and 4 per cent. grade, an example may be found in the North Bloomfield Company's figures, per oz. of metal produced:—

	s.	d.
Labour .. .. .	16	0
Blocks and lumber .. .. .	2	0
Explosives .. .. .	4	0
Materials .. .. .	3	8
General expenses .. .. .	2	11
Water .. .. .	8	0

The following promiscuous costs per yd. may also be quoted:—  
3d. ; 1½d. ; 1¼d. ; 1d. ; 1d. ; averaging from 1d. to 2¾d. per cub. yd.

#### GOLD SLUICING: *Yields and Cost.*

Of the yield from hydraulic workings, those lying between the Middle and South Yuba have averaged, according to Laur, 8d. per cub. yd. and according to Prof. Silliman, 15d. per cub. yd. Various yields have been:—2s. 11½d. ; 2s. 6d. ; 12½d. ; 7½d. ; 6¼d. ; 5d. ; 2¼d. The last mentioned figure refers to the Gold Run district, where all the conditions were extraordinarily unfavourable. The average yield of the Smartsville gravel is stated by Whitney at about 23c. (11½d.) per cub. yd.

*Gold Sluicing—continued.*

In the Sierra Nevada, when the top gravel only is washed, it is thought to do very well if it yields 10c. to 15c. (5*d.* to 7½*d.*) per "inch" of water for 10 hours. On the North Bloomfield Co.'s mine in 1870-71, the yield of surface gravel was 16c. (8*d.*) per "24-hour inch," or 6½c. per "10-hour inch." From 1870 to 1874, the yield was only 13½c. per "24-hour inch," equal to 5½c. per "10-hour inch." In 1875, the top gravel, including a little blue gravel, but nothing within 40 ft. of the bed-rock, yielded 19½c. per "24-hour inch," or 8c. per "10-hour inch." It is quite probable, however, that the water in this mine, furnished as it is from the company's own ditch, is much more lavishly used than in mines where it is purchased, and the relation of water to product would, on that account, be an unfair criterion for other mines. At Columbia Hill, where only top gravel has been washed, its yield in several instances has varied from about 20c. (10*d.*) to 58c. (29*d.*) per "24-hour inch," affording in the instance last referred to exceptionally good profits.

Four companies at Howland Flat and Potosi—the Down East, Union, Hawkeye, and Pittsburg—took from about 2,365,000 sq. ft. of surface, 2,251,653 dols. 95c. (470,094*l.* 6*s.* 5*d.*), the pay-gravel being estimated at 4½ ft. in thickness. This would give an average of 95c. (3*s.* 11½*d.*) per sq. ft. of surface, or 5 dols. 70c. (23*s.* 9*d.*) per cub. yd. of gravel washed. This material was mined, it is stated, at a cost of 47c. (23½*d.*), leaving a profit of 48c. (2*s.*) per sq. ft. At Grass Flat, in the Pioneer Company's ground, the yield per cub. yd. of gravel is said to have been 1 dol. 59c. (6*s.* 7½*d.*)

At Al'an's Flat, Yackandandah, Victoria, the ground washed off was about 30 ft. deep, the water used was 500 gal. a minute, and the inclination of the sluice was 1 in 25; 3 men worked 150 cub. yd. per diem. The daily expenses of a claim were:—

	£	s.	d.
3 men at 8 <i>s.</i> .. .. .	1	4	0
360,000 gal. of water at 0·33 <i>d.</i>	0	10	0
Wear and tear .. .. .	0	6	0
	<hr/>		
	2	0	0

Consequently a yield of  $\frac{4}{5}$  gr. of gold per cub. yd. covered all expenses.

A hydraulic claim on Dunedin Flat, Kumara, New Zealand, yielded 1735 oz. of gold from a block of 22,403 cub. yd., or an average of 31 gr. per cub. yd., working a face 35 ft. deep. Shares in this claim sold readily at 400*l.* each.

Table 98.—*Cost of Producing 1 oz. Troy of Gold in Californian Hydraulic Claims. (Egleston.)*

	La Grange Co.		North Bloomfield Co.	
	\$	£ s. d.	\$	£ s. d.
Water .. .. .	1.43	0 5 11½	2.09	0 8 8½
Labour .. .. .	6.85	1 8 6½	3.93	0 16 4½
Materials .. .. .	1.81	0 7 6½	0.88	0 3 8
Explosives .. .. .	..	..	0.98	0 4 1
Blocks and lumber .. .. .	..	..	0.50	0 2 1
General expenses .. .. .	0.94	0 3 11	0.70	0 2 11
Contingent expenses .. .. .	0.26	0 1 1	..	..
Taxes .. .. .	0.09	0 0 4½	..	..
	11.38	£2 7 5	9.08	£1 17 10

Value of gold = 3l. 17s. 2½d. per oz.

Table 99.—*Yield of Californian Mines.*

	Height of Bank.	Yield per cub. yd.	
		cents.	d.
Smartsville Claims, Yuba Co. .. .. .	112	19.5	9½
Blue Tent, Nevada Co. .. .. .	180	15	7½
North Bloomfield, Nevada Co. .. .. .	180 to 260	4 to 6.5	2 to 3½
Gold Run, Placer Co. .. .. .	200	4.8	2½
Columbia Hill, Milton Co. .. .. .	100	4.33	2¼
La Grange, Stanislaus Co. .. .. .	18 to 100	2.5 to 15.5	1½ to 7½
Patrickville, Stanislaus Co. .. .. .	40 to 60	4.33 to 18.5	2½ to 9½
Dardanelles, Placer Co. .. .. .	150	13	6½

Table 100.—*Cost and Yield per cub. yd.*

of the yield middle cub. yd. yield.	Cost.		Yield.	
	cents.	d.	cents.	s. d.
Roach Hill .. .. .	6	3	60	2 6
Richardson .. .. .	3	1½	15	0 7½
Iowa Hill .. .. .	2.5	1½	71	2 11½
Independence .. .. .	2	1	25	1 0½
Wisconsin .. .. .	2	1	12.5	0 6½

Table 101.—GOLD: *Sluicing Tunnels.*

Name.	Length of Tunnel.	Average Grade of Tunnel.		Cost (reported).
		In. per Sluice Box.	Ft. per 100.	
	ft.			£
North Bloomfield ..	8000	6½ in. per 12 ft.	4½	100,000
American .. ..	3900	10½ " 14 "	6½	28,040
French Corral .. ..	3500	8 " 14 "	4½	33,000
Bedrock .. ..	2600	9 " 14 "	5½	..
Farrell .. ..	2200	6 " 14 "	3½	..
Sweetland Creek.. ..	2200	8 " 14 "	4½	18,000
Manzanita .. ..	1740	7 " 14 "	4½	12,000
Boston .. ..	1600	10½ " 12 "	7½	8,000
English Mine .. ..	1400	12 " 14 "	7	..

The tunnel forms the outlet of the workings, and in it (as well as beyond it) are placed the sluice-boxes for catching the gold. The dimensions of the tunnel will therefore depend on those of the sluices, allowing about 2 to 2½ ft. of extra room; and the size of the sluices will vary in proportion to the quantity of material and water to be passed through them, and the duration of the mining season. For single sluices about 6 ft. square, running 8 or 9 months in the year, a tunnel 8 ft. high and 7 ft. wide is commonly made, which at 4 per cent. grade will consume 2000 to 2500 miners' "inches" of water. For a consumption of 3000 to 3500 miners' "inches" of water, larger tunnels and double sets of sluices are preferable. The grade should be as high as can safely be used, both for the purpose of breaking up the material thoroughly, and to ensure against choking, at the same time that it must not be so steep as to create undue wear and tear of the sluices; it will vary, in inverse proportion to the size of the sluice, from 4 to 7 per cent., commonly the former, and with very light and friable dirt even 3½ per cent. may suffice. In length, tunnels vary according to circumstances from hundreds to thousands of feet; and the depth between their outlet and where they abut on the shaft bottom should be 50 to 70 ft., it being seldom easy to get more.

#### GOLD: *Sluicing Yields.*

The method of stating the yield of deep gravels varies. In some places, the standard is the car-load, calculated at 16-20 cub. ft. = 1 ton; but as the size of the car depends upon the size of the tunnel, the car-load, without giving dimensions, cannot be a standard of value. About 9 cub. ft. of ground in place, when broken, will fill a box of 12 cub. ft. capacity. An estimate, based upon cubing the feet, without explanation, would be erroneous. Another way of estimating the yield is per ft. of channel. In some places the value is expressed at per acre or at per superficial yard of channel-ground, but the height of the ground is not uniform. In some places it is 3, and in others 4 or 5 ft. The only way to definitely express the



*Sluicing—continued.*

value is by the cub. yd., but this method is not in general use, so that it is not easy to get a standard of the value for comparison.

To pay, gravel should contain, under ordinary circumstances, 2s. to 4s. worth of gold per car-load of 16 cub. ft. The minimum value of ground to be worked should thus be 2s. to 4s. per cub. yd. of gravel extracted.

*Yields of Gold from various deep leads.*—One field of 20 acres produced 16,440 oz. of gold; the average at another diggings was 2 dwt. 22 gr. per ton; at a third, 1 to 1½ dwt. per load; at a fourth, 5 dwt. per ton; at a fifth, 6 dwt. per ton; at a sixth, 15 dwt. per load. In a seventh instance, one mile of lead yielded 170,000 oz. equal to 32 oz. per lineal ft. These figures all refer to Victoria, and are on the authority of Brough Smyth. In California, 50c. (say 2s.) per cub. yd. seems to be the average value of the wash-dirt in the deep leads; but Raymond mentions four companies which made respectively 10·80 dols., 8·10 dols., 9·45 dols. and 7·38 dols. per sq. yd., which gives an average of 95c. (3s. 11½d.) per sq. ft. of ground 4½ ft. high, or 5·70 dols. (23s. 9d.) per cub. yd. of gravel.

Table 102.—GOLD: *Sluicing Ditches.*

Name.	Length of Ditch.	Width of Top of Ditch.	Width of Bottom of Ditch.	Depth of Ditch.	Cost of Ditch.	Average Grade per Mile.	Discharge in Miners' Inches.
	miles	ft.	ft.	ft.	£		
Milton .. .. .	100	6	4	3·5	52,000	14·5	3000
North Bloomfield..	55	8·65	5	3·5	84,000	14	3200
.. .. . (1.)	60	8	6	4	..	..	2200
Spring Valley .. (2.)	52	6	4	3·5	..	..	2000
Hendrick's .. ..	46·5	6	4	2	27,000	9·6	..
San Juan .. .. .	45	..	..	..	59,000	..	1300
South Yuba .. .. (3.)	35	8	4	4	..	..	..
Excelsior .. .. .	33	8	5	4	..	9	1700
La Grange .. .. (4.)	20	9	6	4	90,000	7·5	3000
Eureka Lake.. ..	18	..	..	..	86,000	..	2800
Union .. .. .	15	8	4	3·5	..	13	1200
Boyer .. .. .	15	8	4	3·5	..	13	1200
.. .. . (5.)	..	6·5	4	3	..	11·2	3000
.. .. . (6.)	..	..	3	3	..	..	2000

1. On the line of the ditch are 4 miles of iron pipe, 30 in. diameter, one section of which conducts the water across a branch of a river. It is laid as an inverted siphon, and has a vertical depression of 856 ft. The receiving arm has a head of 180 ft. vertical pressure; length of siphon, 2½ miles.

2. This has 3½ miles of 30-in. iron pipe.

3. With a subsidiary ditch, grade 10 ft. per mile, current 2½ ft. deep. It is carried across a narrow cañon by a wire suspension flume, and across another by a truss flume with a span of 60 ft.

4. Most of this ditch is hewn in granite.

5. The line is graded 7½ ft. wide, and excavation made close into the bank, leaving not less than 1 ft. of solid earth on the outside.

6. To cross a creek the water is led into a 27-in. pipe, 420 ft. long, and with a depression and elevation of 75 ft.

Table 103.—GOLD: Sluicing; Working Details of Tunnel Claims near Dogtown, Calaveras County, California.  
(Min. Comr. Rep.)

	Hammerschmidt, Hensel & Co.	Barney, Hurle & Co.	Bully Company.	Buckeye Company.	Deltrich & Co.
Inches of water used in sluice washing	25 to 30	30	30	30	30
Height of fall	20 ft.				
Supply of water lasting in the year	100 ft.	6 to 8 months	6 to 8 months	6 to 8 months	6 to 8 months
Cost of water (sluicing) per day	\$4	\$4	\$4	\$4	\$4
Cost of water (hydraulic) per week	\$20				
Air-shafts	One of 70 ft., one of 148 ft.	One of 105 ft.	4	4	10
Length of tunnel at present	1500 ft.	One of 200, one of 400, and one of 300 ft.	700 ft.	1000 ft.	1200 ft.
Height of drift (all pay-dirt)	6 ft.	$4\frac{1}{2}$ to $6\frac{1}{2}$ ft.	4 ft.		
When this claim commenced	In 1865	In 1862	1870	1870	1870
Area of ground drifted out and worked	9166 superficial sq. yd.	5600 superficial sq. yd.			
Number of cubic yards drifted out	18,332	7500 sq. yd.	3000		
Length of ground unworked	400 ft.	600 ft.	1000 ft.		
Average of cement-gravel extracted per day	20 to 25 car loads; about 25 sq. yd.	15 to 20 sq. yd.	Over one-half		
Quantity of refuse left in the stope	Over one-half	Over one-half	2000 sq. yd.		
Quantity of gravel-cement washed during last year and extracted	2200 sq. yd.	Not washed	\$700.		
Yield of cement-gravel	\$4 to \$5 per sq. yd.	\$4	\$700.		
Total yield last year	Over \$3000	Not washed out			
Total yield since commencement of this claim	\$70,000	\$30,000			
Gold, description	Small flat particles	Both coarse and fine.			
Wages paid to underground-drifters	\$2-50	\$2-50	\$2-50.		
Number of men hired	4				
Number of men working	8				
Composition of deposit	Red soil, small and large white and blue quartz boulders, pieces of dark blue slate, quartz, and mica slate, cemented granite gravel.	Red soil, quartz, gra- vel, slate, granite, sand—all cemented.	Gravel, cemented.	Gravel, cemented.	Gravel, cemented.
Bed-rock	Dark blue slate, full of cubical pyrites.	Dark blue slate, veins of quartz.	Blue slate	Blue slate	Blue slate.
Direction of tunnel and course of deposit-channel	E.N.E.	E.	S.E.	S.E.	S.E.

GOLD: *Sluicing; Cost of Tunnelling at Red Point, Placer Co., Calif.*

It is the intention to tap and work an ancient gravel channel which is known to exist under the ridge forming the upper portion of the Forest Hill divide. For this purpose a tunnel was located in Red Point Cañon, about  $1\frac{1}{2}$  mile above the town of Damascus. An air compressor is located 200 ft. vertical above, and about 300 ft. distant from, the mouth of the tunnel, the air being conveyed through a 3-in. pipe, which in the tunnel has valves and blow-outs every 500 ft. for the purpose of ventilation. There are no other pipes in the tunnel, except a 1-in. water-pipe for drilling use. The tunnel runs diagonally across the strike of the rocks, which consist of alternate strata of slate, impregnated with iron pyrites, diorite, and masses of white barren quartz.

Table 104.—Actual Cost of 1552 ft. of Tunnel  $7 \times 8$ , exclusive of Management, up to February 1, 1887.

	Total.		Cost per running foot.	
	\$	£ s.	\$	£ s. d.
Total labour (pay roll), including 100 ft of timbering . . . . .	11,418·87	2283 15	7·36	1 10 8
Powder. 10,567 lb. Giant No. 2, and 325 lb. No. 1, at 26½ c., 41½ c., 10 per cent. off . . . . .	2,641·64	528 5	1·70	0 7 1
Fuse. 39,650 ft. at \$5·50 per mille, and caps \$45, delivered. . . . .	263·07	52 16	0·17	0 0 8½
Wood. 402 cords, at \$2·75 . . . . .	1,105·50	221 0	0·71	0 2 11½
Charcoal. 1604 bushels, at 20 c. . . . .	320·80	64 0	0·21	0 0 10½
Candles. 1760 lb., at 16½ c. . . . .	290·40	58 0	0·19	0 0 9½
Foot planks and ties. 7355 ft. of lumber, at \$20 per mille . . . . .	147·10	29 10	0·09	0 0 4½
Timbers. 43 sets, at 60 c. per running foot . . . . .	46·76	9 6	0·03	0 0 1½
Steel rails. 16,640 lb., at \$60 per ton . . . . .	510·00	102 0	0·33	0 1 4½
Air and water pipes, 3 and 1 in., at 18 c. and 5½ c. per ft. . . . .	521·86	104 4	0·33	0 1 5½
Horse feed . . . . .	281·25	56 0	0·18	0 0 9
Materials, steel, oil, tools, &c. . . . .	693·00	138 0	0·45	0 1 10½
Freights, at 1·25 per 100 lb. . . . .	1,000·00	201 0	0·64	0 2 8
Totals . . . . .	\$19,239·85	£3847 16	\$12·40	£2 11 8

Table 105.—Cost of Surface Improvements, Plant, and Tunnel.

	Total Cost.		
	\$	£	s.
Road, 6500 ft. long; average grade, 1 ft. in 10. Average force of men per day, 9·2. Including surveys and powder.. . . .	963·00	192	12
Yards, dump and trails. Average force of men, 5·6. Total cost, including crib-work, timber, and powder.	508·05	101	11
Boarding-house, office, blacksmith shop, stable, powder-house, wood-shed, framing sheds, snow-sheds, &c. . .	2,310·10	462	0
Water-works. Long dam, 2-in. pipe line 2800 ft. long, in ditch and covered. Average force of men per day, 2·74. Total cost, including surveys, powder and pipe	604·94	120	16
Air-compressor erection. Average force of men per day, 5. Total cost of labour . . . . .	970·00	194	0
One straight-line compressor, 16 × 16 × 24; one 34 × 16 steel boiler, complete; air-tank; pump, 3 × 3½; eclipse drills and columns; pipe connections, extras, freight, and building 30 × 40.. . . .	7,819·86	1564	5
8 iron cars . . . . .	1,200 00	240	0
2 tunnel horses, 2 team horses, and buckboard . . .	705·00	141	0
Total cost of plant, &c., &c... . .	\$15,080·95	£3016	4

*GOLD: Cost of Alluvial Mining in Victoria (Smyth).*

At Ballarat the average cost of raising and puddling wash-dirt and getting out the gold in several mining properties is 7s. 3d. per ton, and the cost of puddling and sluicing in two instances is 1s. 7½d. per ton.

At Clunes, the average cost in one alluvial mine is 10½d. per ton for puddling, and the average cost of sluicing is 3½d. per ton.

At Sandhurst, the average cost of raising "cement" is 3s. 6d. per ton; the average cost of carting, crushing, and extracting the gold is 8s. per ton; and the average cost of puddling or sluicing is 3s. per ton, including cartage.

At Maryborough, the average cost in three instances of raising cement is 21s. 8d. per ton; puddling, 2s. 6d. per ton.

At Castlemaine, the average cost in one claim of breaking cement is 21s. per ton; raising it to the surface and delivering it at the machine, 4s. 9d. per ton; crushing the cement and extracting the gold, 3s. 9d. per ton. The average cost of puddling by one party of miners is 1s. 2d. per ton.

At Maldon, the average cost in one mine of raising cement and delivering it at the machine is 1s. 6½d. per ton; and the cost of crushing and extracting the gold is 2s. per ton. At the Forty-foot lead, the average cost of raising, carting, and puddling is 6s. 6d. per ton.

At Hurdle Flat, Ovens district, ground 16 ft. 6 in. deep, sluice in rock, 4 gr. of gold (6d. per load) pays well; four men get down and wash 1 ton of dirt every 5 minutes.

GOLD SLUICING : *Nozzles* (Van Wageningen).

To estimate quantity of water discharged from nozzle of pipe, extract the square root of the head, and multiply this root by 8.03; the product will be the velocity in ft. per second with which the water escapes from the mouth-piece. Multiply the area of the mouth-piece by this velocity, and the result will be the discharge in cub. ft. per second. *Ex.*—What quantity of water will be discharged from a pipe, under a head of 100 ft., through a 3-in. nozzle? *Ans.*—The square root of the head (100) is 10, which, multiplied by 8.03, gives 80.3 ft. as the velocity per second. The diameter of nozzle being 3 in. (.25 ft.), its area would be .25 multiplied by 3.14, multiplied by .0625 = .04906 sq. ft., which, multiplied by the velocity 80.3, equals 3.93 cub. ft. discharge per second. The actual discharge is probably about 80 per cent. of the theoretical one in well-made nozzles provided with inside flanges to prevent revolution of the stream, and in this case would be 3.14 cub. ft. per second. This would represent about 115 miners' inches. The power of the stream depends very largely upon its smooth and cylindrical form. The mouth-piece, therefore, should be very smooth, and the arrangements of the pressure or water box so perfect as to exclude all sand, air, and other foreign matters.

GOLD SLUICES : *Dimensions* (Van Wageningen).

The maximum quantity of water which may be advantageously used in a single sluice of correct dimensions when the ground is ordinarily full of boulders, is set down by good practical authorities at 1000 miners' inches. This corresponds to a discharge of 95,000 cub. ft. per hour, which, with gravel and boulders, would represent about double that amount of moving substance in the sluice. When more than this is used the current will be so strong that men cannot work to any advantage in the head-box. Sluices intended to clear off top dirt must be short and large. In this case the top dirt is presumed to be nearly free of gold and of boulders. First decide upon the largest sized boulder which shall be allowed to go through the flume. If it be 2 ft. diameter, the flume must carry at least 2 ft. deep of water. The bottom should be  $1\frac{3}{4}$ – $2\frac{1}{4}$  times the height of the side, or, taking the side at 30 in., the bottom should be  $52\frac{1}{2}$ – $67\frac{1}{2}$  in. wide. If, however, the ground is free from large boulders, it is merely necessary to ascertain the dimensions best adapted to carry the greatest economical quantity of water (1000 in.) or 27.1 cub. ft. per second. Double this discharge to make room for the gravel. The flume must then discharge 54.2 cub. ft. of material per second. Having ascertained the area of section in sq. ft., resolve it into correct dimensions by the following rules :—

*Rule 1.* The width to be  $2\frac{1}{4}$  times the sides.

*Sluices—continued.*

Multiply the area in sq. in. by 4, and divide the product by 9. Extract the square root of the quotient. The result will be the height of side in inches.

*Rule 2.* The width to be  $1\frac{1}{2}$  times the sides.

Multiply the area in sq. in. by 4, and divide the product by 7. Extract the square root of the quotient. The result will be the height of side in inches.

GOLD SLUICES: *Grade* (Van Wagenen).

The moving power of water in sluices may be approximately judged by—

Table 106.

16 ft.	per minute	begins to wear away fine clay.
30 "	"	just lifts fine sand.
39 "	"	lifts sand as coarse as linseed.
45		moves fine gravel.
120	"	inch pebbles.
200	"	pebbles as large as eggs.
320	"	boulders 3-4 in. thick.
400	"	" 6-8 "
600	"	" 12-18 "

Hence following rule for establishment of grades in sluices when the velocity needed is decided upon:—Multiply the velocity expressed in ft. per second by itself, and the product by the wet perimeter in ft. Divide this result by twice the area in sq. ft. The result is the total fall in ft. per mile. *Ex.*—What grade must be given to a sluice 12 in. broad and 6 in. deep, that it may carry a velocity of 320 ft. per minute, or 5·3 per second? *Ans.*—Multiply the velocity (5·3) by itself, and the product by the wet perimeter (24 in. = 2 ft.), we have 56·18. This, divided by the area (72 sq. in. = ·5 ft.), and doubled = 56·18, which is the fall in ft. per mile. To reduce grades expressed in ft. per mile to in. per box of 12 ft. multiply by ·027. Thus, a grade of 56·18 ft. per mile equals a grade of 1·5 ( $1\frac{1}{2}$ ) in. per box. To reduce to in. per rod (16 ft.), multiply by ·036.

GOLD SLUICING: *Specification of Stores Required for Opening Hydraulic Mine.* (Kirkpatrick.)

- 10 cwt.  $\frac{7}{8}$ -in. borer steel.
- 1 doz. steel mallets for boring, 7 lb.
- 12 hand-saw files.
- 3 tenon-saw files.
- 15 6-in. pit-saw files.
- 15 8-in. cross-cut saw files.
- 3 smiths' sledge hammers, 9 lb.
- 1 cwt. cast steel for steeling picks.

*Specification—continued.*

- 1 doz. riveting hammers.
- 1 doz. set tools for  $\frac{1}{4}$ -in. rivets.
- 1 doz. snap tools.
- 6 hand hammers, Nos. 10 and 12 tester heads.
- 10 doz. miners' steel shovels, diamond points.
- 5 doz. Cornish picks.
- 10 doz. handles for ditto.
- 1 doz. long Colonial pattern felling axes.
- 2 small portable forges.
- 1 best black staple smiths' vice.
- 2 anvils (farriers' pattern), 150 lb. each.
- 2 grindstones 27 in. diam. (1 coarse, 1 fine).
- 2 sets screw stocks, dies, taps, and wrenches complete, from  $\frac{1}{16}$  in. to  $\frac{3}{4}$  in. and  $\frac{1}{4}$  in. to  $1\frac{1}{4}$  in. engineers'.
- 3 expanding spanners.
- 20 cwt. best cut nails  $2\frac{1}{2}$  in.
- 10 cwt. " " "  $3\frac{1}{2}$  "
- 16 cwt. " " " 4 "
- 4 cwt. " " "  $4\frac{1}{2}$  "
- 4 cwt. " " " 5 "
- 4 cwt. spikes, 7-in.
- 4 cwt. " 9 "
- 1 doz. riveting blocks.
- 2 doz. pairs of tools for riveting pipes.
- 500 lugs for ditto.
- 4 sets carpenters' bench planes (jack, trying, and smoothing).
- 4 3-in. bench screws and nuts.
- 6 4-lb. carpenters' axes, with handles.
- 2 sets socket mortice chisels, with handles.
- 3 pair 12-in. wing compasses.
- 6 2-ft. rules to fold 12 in.
- 2 " " " " 6 "
- 4 carpenters' set stones.
- 2 pair pincers.
- 2 2-ft. iron squares, graduated inches.
- 4 14-in. carpenters' plated squares.
- 4 6-in. " "
- 4 doz. carpenters' pencils.
- 3 spirit levels, set in straight edge 30 in. long, with handle on top to protect level.
- 6 hand-saws (7 teeth to inch).
- 4 fine ditto, for cross cutting.
- 4 carpenters' table saws.
- 3 12-in. tenon saws.
- 4 7-ft. pit saws (for pine)
- 6 5-ft. cross-cut saws (for oak) } complete with bow and gear.
- 2 iron braces, 24 bits to each.
- 4 carpenters' marking mortices.

*Specification—continued.*

- 4 hand-saw sets.
  - 6 pit-saw sets.
  - 6 14-in. drawing knives.
  - 3 plated spokeshaves.
  - 6 12-in. turnscrows.
  - 2 ploughs and irons.
  - 6 adzes (12-in. handles).
  - 6  $\frac{1}{2}$ -in. screw augers.
  - 6  $\frac{3}{4}$ -in. augers.
  - 6  $\frac{7}{8}$ -in.
  - 6  $1\frac{1}{8}$ -in.
  - 3  $1\frac{1}{2}$ -in.
  - 3  $1\frac{3}{4}$ -in.
  - 3 2-in.
  - 3 doz. caulking irons, single crease.
  - 4 plated angle bevels.
  - 2 joiners' cramps, 6 ft. long.
  - 60 ft.  $1\frac{1}{2}$ -in. bar iron.
  - 130 lb. soft iron wire, No. 12 B.W.G.
  - 1 cwt. white lead.
  - 16 door locks (different).
  - 2 doz. padlocks.
  - 5 doz. 4-in. butt hinges.
  - 2 gross  $1\frac{1}{2}$ -in. screws.
  - 1 gross 1-in. screws.
  - 7 gross smaller (for locks).
  - 10 pieces of unbleached calico (for making tight joints in pipe).
  - 2 doz. ordinary iron buckets.
  - 2 doz. black iron scoops.
  - 1 doz. hard brushes.
  - 20 bottles mercury.
  - 2 No. 5 "monitors," with deflectors and nozzles.
  - 2 18-in. vacuum valves.
  - 2500 ft. 18-in. diameter pipe, No. 14 B.W.G.,  $\frac{1}{4}$ -in. rivets.
  - 500 ft. 15-in. diameter pipe, No. 14 B.W.G.,  $\frac{1}{4}$ -in. rivets.
  - 100 ft. 30-in. diameter, tapering to 18-in., No. 14 B.W.G., and  $\frac{1}{4}$ -in. rivets.
  - 2400 ft. run of 11-in. by 3-in. timber, cut into 11-in. by  $1\frac{1}{2}$ -in., in 20-22 ft. lengths, second St. Petersburg deals.
  - 4000 ft. run 6-in. by 4-in., in 12-22 ft. lengths, third St. Petersburg deals.
  - 1 small distributor.
  - Melting pots, ingot moulds.
  - Chemicals—borax, carbonate of potash and soda, &c.
  - Tongs, cobbing hammers, and iron plates.
  - Blankets, cold chisels, scales and weights.
  - Red lead, litharge.
- The cost of the above will be under 2,000*l*.



*GOLD: Cost and Profit of Quartz Mines.*

Circumstances vary so widely at different mines that no general estimate of cost or profit could possibly be deduced in a form that would have any practical value; but it may be useful to quote the prices paid for crushing quartz in Victoria. These range from a minimum of 4s. to a maximum of 15s. a ton, the majority being about 5s. a ton where water power is available, to 8s. and upwards where the motor is steam. The success of a quartz mine depends quite as much on favourable working conditions as on richness in gold. Hence it may happen that a mine carrying 5 oz. of gold to the ton, but badly situated, may be inferior as an investment to another showing only 5 dwt., but favourably circumstanced. There are a great many mines where 3 to 4 dwt. of gold cover every item of expenditure, the excess being clear profit. In fact, one Victorian mine, in the Blackwood Division, satisfied its owners with a yield of  $1\frac{1}{2}$ ·2 dwt. a ton, crushing with water power. On the other hand, mines which have been credited with giving extraordinary assay values have not paid for working. So much depends on local conditions and proper management.

*GOLD AMALGAMATING: Copper Plates.*

From inquiries made of a number of Australian managers, the following inclines per ft. are recommended for copper plates, viz.,  $\frac{1}{2}$  in.,  $\frac{3}{4}$  in.,  $\frac{7}{8}$  in., 1 in.,  $1\frac{1}{8}$  in.,  $1\frac{3}{8}$  in.,  $1\frac{1}{2}$  in.,  $1\frac{3}{4}$  in.,  $1\frac{7}{8}$  in., or an average of exactly 1 in. per ft. Bland finds amalgamated plates less efficient than mercury drops and blanket tables, and mentions that the incline depends greatly upon the supply of water—the smaller the supply the greater must be the incline. Clark states that copper plates are generally laid on the ripple tables between the wells of mercury, the object being to bring every particle of the crushed sand, as it escapes from the battery, in contact, as far as possible, with the surface of the mercury, or with the silvered surface of the copper plates. The incline of  $1\frac{7}{8}$  in. has been found to work very well for all kinds of stone operated upon, just enough water being used to clear the table. Too much water is objectionable, as it is likely to carry away fine gold. Parker remarks that a great deal depends upon the width of the tables; if they are made the full width of the boxes, more water must be used, or the incline must be greater. Where tables are narrowed to suit the discharge of the gratings, the plate laid immediately under the lip of the box should not have a greater incline than  $\frac{3}{4}$  in. per ft. The second plate leading to the blanket strakes should have an incline of 1 in. per ft., and the blanket table  $1\frac{1}{2}$  in. per ft. If the tables are the full width of the boxes, the top plate should have  $\frac{7}{8}$  in. incline, and the second plate  $1\frac{1}{8}$  in. per ft. It must be understood

*Amalgamating—continued.*

that this last paragraph refers only to plates laid outside the mortar or coffer, as few, if any, Australian mills have plates inside the mortar.

GOLD AMALGAMATING: *Arrastra.*

The working capacity of the simplest arrastra varies from 1 to 2 tons a day. A 12-ft. arrastra driven by power, with heavy drags, making 15 revolutions per minute, may treat two charges of 2 tons of ordinary ore in 24 hours, if very close work is not necessary; but this is the extreme limit of its capacity. The labour required is extremely small. One man per shift can easily take care of two arrastras. Sometimes, when working on tailings, and running by water power, the disposition of the mill is such that the only labour required is for feeding and discharging, being much less than the work of one man. The owner of the mill may do all the work himself. With continuous action, the labour is still smaller, being simply that needed for repairs. Where water power is available, small overshot wheels, or turbine "hurdygurdies," are used. A simple arrastra for mule power can be built for 20% to 30%. The cost of 26 complete mills, having 92 arrastras, in 1880, was 137,590 dols., or an average of 5292 dols. for each works, or 1495 dols. (say 75%) per arrastra, including all the rest of the plant. This is considerably above the cost of ordinary arrastra mills. The arrastra at Seales and Wagner's works, Owyhee Co., Idaho (one of the best), produced in 1880 about 10,000%. The charge for treating custom ore in lots of 100 tons and over, is 15 dols.; for lots of 50-100 tons, 16 dols.; and a corresponding increase for smaller lots. The plant consists of a battery of 10 light stamps, 2 arrastras, 3 half-ton Wheeler pans, 2 settlers, and a retort.

Table 107.—*Arrastra*: Working figures in summer, on a 12 hours' shift:—

	\$	£ s. d.
4 men inside the mill at \$4 per 12 hours' shift .. .. .	16·00	3 4 0
2 labourers in the summer, on 10 hours' shift outwork, at \$3·50 .. .. .	7·00	1 8 0
2 engineers in winter, on 12 hours' shift, at \$5 .. .. .	10·00	2 0 0
Number of days' work, 330 .. .. .	..	..
Hours of labour to treat 1 ton of ore, 12·7 .. .. .	..	..
Cost of supplies per ton of ore treated .. .. .	3·95	0 16 0 *
Tons of ore treated in 1880 (tails about 300 tons), 1772·25 ..	..	..
Lowest yield of ore .. .. .	38·00	7 12 0
Highest yield of ore .. .. .	600·00	120 0 0
Average .. .. .	115·85	23 3 6
Yield of the tails .. .. .	9·50	1 18 0

Table 108.—*Arrastra*: Amount of supplies consumed, and amount per ton of ore treated:—

Items.	Total Consumption.		Consumption per ton of Ore treated.		
	Amount.	Cost.	Amount.	Cost.	
		\$ c.		\$ c.	s. d.
Red fir .. .. . cords	575	4,168 75	0·32	2 35	9 5
Quicksilver .. .. . lb.	3,000	1,440 0	1·69	0 81	3 4
Salt .. .. . "	14,000	420 0	7·89	0 24	1 0
Bluestone.. .. . "	3,000	750 0	1·69	0 42	1 9
Lard oil .. .. . gal.	20	40 0	0·01	0 2	0 1
Chemicals and sundries ..	..	200 0	..	0 11	0 5
Total .. .. .	..	7,018 75	..	3 95	16 0

GOLD AMALGAMATION: *Mercury, purifying* (Kirkpatrick).

The pellicle formed on mercury by absorption of oxygen from the air, can be removed by passing a large and *quite dry* glass tube over the surface, rolling it gently. Or, add a little concentrated sulphuric acid to the mercury in a stoneware dish or glass bottle, and shake about till the mercury is broken up and thoroughly brought into contact. Leave for 2–3 days, and then wash completely and repeatedly in clean water.

To remove metallic impurities, after redistillation, replace the mercury in the iron bottle, add nitric acid mixed with a double volume of water, and heat to 150° F. Leave the acid in the bottle for 24 hours, shaking well occasionally. Then drive off the water by gently heating the bottle. Remove the crust of nitrate of mercury, and wash *thoroughly* with clean water.

GOLD: *Chlorination by Plymouth Co.*

They treat 100 tons of concentrates per month of 30 days. The leaching occupies only 24 days in the month.

Table 109.—*Chlorination* : Expenses per month.

Roasting.							
						\$	c.
3 men at \$2.50 a day for 30 days .. .. .						225	00
14 cords wood at \$4.25 .. .. .						223	13
54 lb. salt at 4 c. .. .. .						12	15
						<hr/>	
						460	28
Chlorine.							
60 lb. manganese per day at \$47 per ton .. .. .						33	84
68 lb. salt per day at \$15 .. .. .						12	24
120 lb. acid per day at \$60 .. .. .						86	40
						<hr/>	
						132	48
Leaching.							
40 lb. sulphuric acid for 24 days .. .. .						57	60
40 lb. sulphate of iron for 24 days .. .. .							
1 leacher at \$5.50 for 30 days .. .. .						165	00
Salary of foreman .. .. .						125	00
						<hr/>	
						347	60
						<hr/>	
						940	36

Or, per ton of concentrates, \$9.403.

At the Providence Mine are 2 roasting furnaces of the capacity of 9 tons in 24 hours. Each furnace requires 1 cord of wood in that time.

Table 110.—*Chlorination* : Cost per diem.

	\$	c.	£	s.	d.
1 foreman .. .. .	3	00	0	12	0
1 white labourer .. .. .	9	25	1	17	0
5 Chinamen at \$1.50 .. .. .	7	50	1	10	0
2 cords wood at \$5 .. .. .	10	00	2	0	0
29 lb. binoxide manganese at 2½ c. .. .. .	0	80	0	3	4
260 lb. salt at 1 c. .. .. .	2	60	0	10	6
216 lb. sulphuric acid at 2 c. .. .. .	4	32	0	17	6
Line, sulphur, and calcium hyposulphite .. .. .	0	30	0	1	3
Illuminating .. .. .	0	20	0	0	10
Extras .. .. .	1	00	0	4	0
Total .. .. .	38	97	7	16	4

This makes the cost of treatment per ton of sulphurets 3.55 dols. (14s. 9d.) when the works are run at full capacity. But the ore contains about 7 per cent. of sulphurets, or  $4\frac{1}{3}$  tons in the 62 tons milled daily. This quantity of sulphurets does not keep the two furnaces running at full capacity, but both are in continual operation. Most of the expenses remain the same whether running at full capacity or not; the actual cost, therefore, figured on a working basis of  $4\frac{1}{3}$  tons daily capacity, approximates as in Table 111.

Table 111.—*Chlorination*: Cost per ton.

	\$ c.	£ s. d.
Labour .. .. .	12 75	2 13 2
2 cords wood at \$5.00 .. .. .	10 00	2 1 7
14 lb. binoxide manganese at 2½ c. .. .. .	0 38	0 1 7
126 lb. salt at 1 c. .. .. .	1 26	0 5 3
104 lb. sulphuric acid at 2 c. .. .. .	2 08	0 8 8
Lime, sulphur, and calcium hyposulphite .. .. .	0 15	0 0 8
Illuminating .. .. .	0 20	0 0 10
Extras .. .. .	0 50	0 2 1
Total per day .. .. .	27 32	5 13 10
Adding to this the cost for milling per day .. .. .	57 50	11 19 7
The total outlay per day equals .. .. .	84 82	17 13 5

Or \$1.37 (5s. 8d.) per ton for extracting the gold and silver from the ore.

This estimate makes no allowance for the expenses of general supervision, interest on first cost, and gradual deterioration. The conditions of treatment in these works are, however, very special, and can hardly be considered as a basis for the general cost of treatment elsewhere.

Table 112.—GOLD: *Cost of Chlorinating 5136 tons of Sulphurets at Sutter Creek.*

Expense.	Total Amount.	Lb. per ton.	Cost per ton.		
	\$ c.		\$ c.	£ s. d.	
Labour and superintendent's salary, at \$200 per month .. .. .	39,339 00	..	7 66	1 11 11	
82 tons peroxide of manganese, at \$40 per ton .. .. .	3,280 00	32	0 64	0 2 8	
128 tons salt, at \$15 per ton .. .. .	1,920 00	50	0 38	0 1 7	
308,160 lb. sulphuric acid, 66°, at 3½ c. per lb. .. .. .	10,785 60	60	2 10	0 8 9	
256½ cords of wood, at \$8 per cord .. .. .	15,408 00	½ cord.	3 00	0 12 6	
General expenses for 6 years, including assaying, repairing, sundry supplies, hose, tools, &c., insurance, taxes, water, new vats, interest on capital invested, repairs on furnace and buildings .. .. .	19,003 20	..	3 70	0 15 5	
Total expense .. .. .	89,735 80	..	17 48	3 12 10	

Table 113.—GOLD: *Chlorination; Cost by barrel process at Haile, South Carolina (Thies).*

Working on 4 tons daily.										\$ c.	£ s. d.
40 lb. lime chloride, at 3 c.	..	..	..	..	..	..	..	..	..	1 20	0 5 0
60 lb. sulphuric acid, at 2 c.	..	..	..	..	..	..	..	..	..	1 20	0 5 0
2 labourers, at 90 c.	..	..	..	..	..	..	..	..	..	1 80	0 7 6
1 chlorinator	..	..	..	..	..	..	..	..	..	2 0	0 8 4
Motive power	..	..	..	..	..	..	..	..	..	0 50	0 2 1
Sulphuric acid for making iron sulphate	..	..	..	..	..	..	..	..	..	0 12½	0 0 6
Repairs and wear	..	..	..	..	..	..	..	..	..	0 20	0 0 10
Total										\$7 2½	£1 9 3

Or, \$1 75 c. (7s. 4d.) per ton.

Table 114.—GOLD: *Chlorination; Cost at Bunker Hill.*

										\$ c.	£ s. d.
Labour, per ton	..	..	..	..	..	..	..	..	..	4 75	0 19 9
Power and water	..	..	..	..	..	..	..	..	..	0 50	0 2 1
Wood, ½ cord at \$6	..	..	..	..	..	..	..	..	..	3 75	0 15 8
30 lb. lime chloride, at 4 c.	..	..	..	..	..	..	..	..	..	1 20	0 5 0
36 lb. sulphuric acid, 66°, at 3½ c.	..	..	..	..	..	..	..	..	..	1 26	0 5 3
20 lb. salt, at ½ c.	..	..	..	..	..	..	..	..	..	0 15	0 0 8
General expenses—assaying, melting, taxes, insurance, repairing, loss of material in handling, interest, &c.	..	..	..	..	..	..	..	..	..	3 00	0 12 6
Total										\$14 61	£3 0 11

Table 115.—GOLD: *Chlorination; Estimated cost by Plattner Process.*

										\$ c.	£ s. d.
Labour	..	..	..	..	..	..	..	..	..	4 00	0 16 8
Wood	..	..	..	..	..	..	..	..	..	3 00	0 12 6
Peroxide manganese	..	..	..	..	..	..	..	..	..	0 65	0 2 9
Salt	..	..	..	..	..	..	..	..	..	0 35	0 1 5
Sulphuric acid	..	..	..	..	..	..	..	..	..	2 00	0 8 4
Incidentals—taxes, insurance, ordinary repairs, iron sulphate, assaying material, &c.	..	..	..	..	..	..	..	..	..	3 00	0 12 6
Total										<u>\$13 00</u>	<u>£2 14 2</u>

Table 116.—GOLD: *Lixiviation with Hyposulphites at Bertrand Mill.*

Labour per 24 hours for treating 50–60 tons.

		\$ c.	\$ c.	£ s. d.
Roasters—furnace men .. .. .	2 at	4 00	8 00	1 12 0
„ —feeders .. .. .	2 „	3 00	6 00	1 4 0
Driers and rollers .. .. .	10 „	3 00	30 00	6 0 0
Cooling-floor .. .. .	6 „	3 00	18 00	3 12 0
Leaching-floor, Chinamen .. .. .	2 „	2 50	5 00	1 0 0
„ „ „ .. .. .	3 „	1 50	4 50	0 18 0
Rock breakers.. .. .	2 „	3 00	6 00	1 4 0
Flue cleaners .. .. .	4 „	1 50	6 00	1 4 0
Blacksmith .. .. .	1 „	6 00	6 00	1 4 0
„ helper.. .. .	1 „	3 00	3 00	0 12 0
Carpenters .. .. .	2 „	5 00	10 00	2 0 0
Engineer .. .. .	1 „	5 00	5 00	1 0 0
„ .. .. .	1 „	4 00	4 00	0 16 0
Fireman .. .. .	1 „	2 50	2 50	0 10 0
Assayer .. .. .	1 „	5 00	5 00	1 0 0
Lamp cleaner .. .. .	1 „	1 50	1 50	0 6 0
Foreman .. .. .	1 „	6 00	6 00	1 4 0
„ .. .. .	1 „	5 00	5 00	1 0 0
Office helper .. .. .	1 „	1 50	1 50	0 6 0
General helper .. .. .	1 „	3 00	3 00	0 12 0
Watchman .. .. .	1 „	3 00	3 00	0 12 0
Woodmen, Chinamen .. .. .	3 „	1 50	4 50	0 18 0
	1 „	3 00	3 00	0 12 0
		\$146 50	£29 6 0	

All the charging, discharging, and leaching are done by 4 Chinamen and 3 Irishmen. The total cost of milling the ore is 6·25 dols. (26s.) per ton. The cost of mining and delivering the ore at the mill is about 2·50 dols. (10s.), which makes the total cost about 9 dols. (36s.) per ton of actual expense on each ton of 30-oz. ore.

Table 117.—GOLD: *Roasting and Grinding Pyrites at Port Phillip.*

Cost per ton—	£ s. d.
Buddle expenses .. .. .	1 1 8
Roasting—Labour, 13s. 3d.; fuel, 9s. .. .. .	1 2 3
Grinding, labour .. .. .	0 13 3
Mercury lost, 1 lb. 6½ oz., value .. .. .	0 4 3
Total cost per ton .. .. .	3 1 5
Cost per oz. of gold obtained.. .. .	0 13 2

Table 118.—GOLD: *Roasting and Grinding Pyrites at Walhalla.*

Firewood .. .. .	s. d.
Wages .. .. .	13 0
Repairs, cleaning flue, &c. .. .. .	16 7
	4 2
Per ton .. .. .	33 9

Table 119.—GOLD: *Converting Percentages into Troy Weight per Statute Ton.*

Percentage.	Per ton.	Percentage.	Per ton.
	oz. dwt. gr.		oz. dwt. gr.
0·0001	0 0 15·68	0·06	19 12 0
0·0002	0 1 7·36	0·07	22 17 8
0·0003	0 1 23·01	0·08	26 2 16
0·0004	0 2 14·72	0·09	29 8 0
0·0005	0 3 6·40	0·1	32 13 8
0·0006	0 3 22·08	0·2	65 5 16
0·0007	0 4 13·76	0·3	98 0 0
0·0008	0 5 5·44	0·4	130 13 8
0·0009	0 5 21·12	0·5	163 6 16
0·001	0 6 12·8	0·6	196 0 0
0·002	0 13 1·6	0·7	228 13 8
0·003	0 19 14·4	0·8	261 6 16
0·004	1 6 3·2	0·9	294 0 0
0·005	1 12 16·0	1·0	326 13 8
0·006	1 19 4·8	2·0	653 6 16
0·007	2 5 17·6	3·0	980 0 0
0·008	2 12 6·4	4·0	1306 13 8
0·009	2 18 19 2	5·0	1633 6 16
0·01	3 5 8·0	6·0	1960 0 0
0·02	6 10 16·0	7·0	2286 13 8
0·03	9 16 0·0	8·0	2613 6 16
0·04	13 1 8·0	9·0	2940 0 0
0·05	16 6 16·0	10·0	3266 13 8

Ex.—500 gr. ore gave 0·044 gr. gold, what is the yield per ton?

100 gr. of the ore will give  $0·044 \div 5 = 0·0088$  gr.; and

Per cent. oz. dwt. gr.  
According to table 0·008 = 2 12 6·4  
" " 0·0088 = 0 5 5·44

So  $0·0088 = 2 17 11·84$  per ton.



Table 120. — GOLD: Reckoner, by which the Value of any number of oz., dwt., and gr. may be readily calculated.

At per oz.	Oz.				Dwt.										Gr.				At per oz.
	2	3	4		1	2	3	4	5	6	7	8	9	10	1	2	3	4	
£ s. d.	£ s. d.	£ s. d.	£ s. d.	£ s. d.	£ s. d.	£ s. d.	£ s. d.	£ s. d.	£ s. d.	£ s. d.	£ s. d.	£ s. d.	£ s. d.	£ s. d.	£ s. d.	£ s. d.	£ s. d.	£ s. d.	£ s. d.
2 10 0	5 0 0	7 10 0	10 0 0	12 0 0	3 0 0	6 0 0	9 0 0	12 0 0	15 0 0	18 0 0	21 0 0	24 0 0	27 0 0	30 0 0	33 0 0	36 0 0	39 0 0	42 0 0	45 0 0
2 12 6	5 5 0	7 17 6	10 10 0	12 8 0	3 7 7	7 2 7	10 9 4	14 4 1	17 1 7	19 9 4	22 6 7	25 4 0	28 1 3	30 9 0	33 6 3	36 3 6	39 0 9	41 7 6	44 4 0
2 15 0	5 10 0	8 5 0	11 0 0	14 0 0	3 12 0	6 5 0	9 10 0	12 10 0	15 10 0	18 10 0	21 10 0	24 10 0	27 10 0	30 10 0	33 10 0	36 10 0	39 10 0	42 10 0	45 10 0
2 17 6	5 15 0	8 12 6	11 10 0	14 10 0	3 17 6	7 10 6	10 17 6	14 10 6	17 10 6	20 10 6	23 10 6	26 10 6	29 10 6	32 10 6	35 10 6	38 10 6	41 10 6	44 10 6	47 10 6
3 0 0	6 0 0	9 0 0	12 0 0	15 0 0	3 0 0	6 0 0	9 0 0	12 0 0	15 0 0	18 0 0	21 0 0	24 0 0	27 0 0	30 0 0	33 0 0	36 0 0	39 0 0	42 0 0	45 0 0
3 12 0	7 4 0	10 16 0	14 8 0	18 0 0	3 7 7	7 2 7	10 9 4	14 4 1	17 1 7	19 9 4	22 6 7	25 4 0	28 1 3	30 9 0	33 6 3	36 3 6	39 0 9	41 7 6	44 4 0
3 12 6	7 5 0	10 17 6	14 10 0	18 10 0	3 8 1	7 3 1	11 0 4	14 5 1	17 2 4	20 0 1	22 7 4	25 5 0	28 2 3	31 0 0	33 7 3	36 4 6	39 1 9	41 8 6	44 5 0
3 13 0	7 6 0	10 19 0	14 12 0	18 12 0	3 8 6	7 3 6	11 0 9	14 5 6	17 2 9	20 0 6	22 7 9	25 5 6	28 3 3	31 1 0	33 8 3	36 5 6	39 2 9	41 9 6	44 6 0
3 15 0	7 10 0	11 5 0	15 0 0	18 10 0	3 9 0	7 4 0	11 1 0	14 6 0	17 3 0	20 0 0	22 7 0	25 4 0	28 1 0	30 8 0	33 5 0	36 2 0	38 9 0	41 6 0	44 3 0
3 15 3	7 10 6	11 5 6	15 1 0	18 10 6	3 9 3	7 4 6	11 1 6	14 6 6	17 3 6	20 0 6	22 7 6	25 4 6	28 1 6	30 8 6	33 5 6	36 2 6	38 9 6	41 6 6	44 3 6
3 15 6	7 11 0	11 6 0	15 2 0	18 11 0	3 9 6	7 5 0	11 2 0	14 7 0	17 4 0	20 1 0	22 8 0	25 5 0	28 2 0	31 0 0	33 7 0	36 4 0	39 1 0	41 7 0	44 4 0
3 15 9	7 11 6	11 6 6	15 3 0	18 11 6	3 10 0	7 5 6	11 2 6	14 7 6	17 4 6	20 1 6	22 8 6	25 5 6	28 2 6	31 0 6	33 7 6	36 4 6	39 1 6	41 7 6	44 4 6
3 16 0	7 12 0	11 8 0	15 4 0	18 12 0	3 10 3	7 6 0	11 3 0	14 8 0	17 5 0	20 2 0	22 9 0	25 6 0	28 3 0	31 1 0	33 8 0	36 5 0	39 2 0	41 8 0	44 5 0
3 16 3	7 12 6	11 8 6	15 5 0	18 12 6	3 10 6	7 6 6	11 3 6	14 8 6	17 5 6	20 2 6	22 9 6	25 6 6	28 3 6	31 1 6	33 8 6	36 5 6	39 2 6	41 8 6	44 5 6
3 16 6	7 13 0	11 9 0	15 6 0	18 13 0	3 10 9	7 7 0	11 4 0	14 9 0	17 6 0	20 3 0	23 0 0	25 7 0	28 4 0	31 2 0	33 9 0	36 6 0	39 3 0	41 9 0	44 6 0
3 16 9	7 13 6	11 10 0	15 7 0	18 13 6	3 11 0	7 7 6	11 4 6	14 9 6	17 6 6	20 3 6	23 0 6	25 7 6	28 4 6	31 2 6	33 9 6	36 6 6	39 3 6	41 9 6	44 6 6
3 17 0	7 14 0	11 11 0	15 8 0	18 14 0	3 11 3	7 8 0	11 5 0	15 0 0	17 7 0	20 4 0	23 1 0	25 8 0	28 5 0	31 3 0	34 0 0	36 7 0	39 4 0	42 0 0	44 7 0
3 17 3	7 14 6	11 11 6	15 9 0	18 14 6	3 11 6	7 8 6	11 5 6	15 0 6	17 7 6	20 4 6	23 1 6	25 8 6	28 5 6	31 3 6	34 0 6	36 7 6	39 4 6	42 0 6	44 7 6
3 17 6	7 15 0	11 12 0	15 10 0	18 15 0	3 11 9	7 9 0	11 6 0	15 1 0	17 8 0	20 5 0	23 2 0	25 9 0	28 6 0	31 4 0	34 1 0	36 8 0	39 5 0	42 1 0	44 8 0
3 17 9	7 15 6	11 12 6	15 11 0	18 15 6	3 12 0	7 9 6	11 6 6	15 1 6	17 8 6	20 5 6	23 2 6	25 9 6	28 6 6	31 4 6	34 1 6	36 8 6	39 5 6	42 1 6	44 8 6
3 18 0	7 16 0	11 13 0	15 12 0	18 16 0	3 12 3	7 10 0	11 7 0	15 2 0	17 9 0	20 6 0	23 3 0	26 0 0	28 7 0	31 5 0	34 2 0	36 9 0	39 6 0	42 2 0	44 9 0
3 18 3	7 16 6	11 14 0	15 13 0	18 16 6	3 12 6	7 10 6	11 7 6	15 2 6	17 9 6	20 6 6	23 3 6	26 0 6	28 7 6	31 5 6	34 2 6	36 9 6	39 6 6	42 2 6	44 9 6
3 18 6	7 17 0	11 15 0	15 14 0	18 17 0	3 13 0	7 11 0	11 8 0	15 3 0	18 0 0	20 7 0	23 4 0	26 1 0	28 8 0	31 6 0	34 3 0	37 0 0	39 7 0	42 3 0	45 0 0
3 18 9	7 17 6	11 15 6	15 15 0	18 17 6	3 13 3	7 11 6	11 8 6	15 3 6	18 0 6	20 7 6	23 4 6	26 1 6	28 8 6	31 6 6	34 3 6	37 0 6	39 7 6	42 3 6	45 0 6
3 19 0	7 18 0	11 17 0	15 16 0	18 18 0	3 13 6	7 12 0	11 9 0	15 4 0	18 1 0	20 8 0	23 5 0	26 2 0	29 0 0	31 7 0	34 4 0	37 1 0	39 8 0	42 4 0	45 1 0
3 19 3	7 18 6	11 17 6	15 17 0	18 18 6	3 13 9	7 12 6	11 9 6	15 4 6	18 1 6	20 8 6	23 5 6	26 2 6	29 0 6	31 7 6	34 4 6	37 1 6	39 8 6	42 4 6	45 1 6
3 19 6	7 19 0	11 18 0	15 18 0	18 19 0	3 14 0	7 13 0	11 10 0	15 5 0	18 2 0	20 9 0	23 6 0	26 3 0	29 1 0	31 8 0	34 5 0	37 2 0	39 9 0	42 5 0	45 2 0
3 19 9	7 19 6	11 18 6	15 19 0	18 19 6	3 14 3	7 13 6	11 10 6	15 5 6	18 2 6	20 9 6	23 6 6	26 3 6	29 1 6	31 8 6	34 5 6	37 2 6	39 9 6	42 5 6	45 2 6
4 0 0	8 0 0	12 0 0	16 0 0	20 0 0	4 0 0	8 0 0	12 0 0	16 0 0	20 0 0	24 0 0	28 0 0	32 0 0	36 0 0	40 0 0	44 0 0	48 0 0	52 0 0	56 0 0	60 0 0

Table 121.—Quantity of Fine Gold in 1 oz. of any alloy to  $\frac{1}{8}$  Carat, and the Mint Value of the Gold in 1 oz. of each Alloy.

Fine Gold.			Carat Gold.			Sterling Value.		
oz.	dwt.	gr.	carats.	gr.	eighths.	£	s.	d.
1	0	0	24	0	0	4	4	11.454
0	19	4	23	0	0	4	1	4.977
0	18	8	22	0	0	3	17	10.500
0	17	12	21	0	0	3	14	4.023
0	16	16	20	0	0	3	10	9.545
0	15	20	19	0	0	3	7	3.064
0	15	0	18	0	0	3	3	8.590
0	14	4	17	0	0	3	0	2.113
0	13	8	16	0	0	2	16	7.636
0	12	12	15	0	0	2	13	1.159
0	11	16	14	0	0	2	9	6.682
0	10	20	13	0	0	2	6	0.204
0	10	0	12	0	0	2	2	5.727
0	9	4	11	0	0	1	18	11.250
0	8	8	10	0	0	1	15	4.773
0	7	12	9	0	0	1	11	10.295
0	6	16	8	0	0	1	8	3.818
0	5	20	7	0	0	1	4	9.341
0	5	0	6	0	0	1	1	2.863
0	4	4	5	0	0	0	17	8.386
0	4	8	4	0	0	0	14	1.909
0	3	12	3	0	0	0	10	7.432
0	2	16	2	0	0	0	7	0.954
0	2	0	1	0	0	0	3	6.477
0	1	4	0	3	0	0	2	7.858
0	0	8	0	2	0	0	1	9.239
0	0	16	0	1	0	0	0	10.619
0	0	24	0	0	7	0	0	9.292
0	0	3.750	0	0	6	0	0	7.964
0	0	3.125	0	0	5	0	0	6.637
0	0	2.500	0	0	4	0	0	5.309
0	0	1.875	0	0	3	0	0	3.982
0	0	1.250	0	0	2	0	0	2.655
0	0	0.625	0	0	1	0	0	1.327

	£	s.	d.
1 oz. pure gold is worth	..	..	..
1 dwt.     "     "	..	..	..
1 gr.     "     "	..	..	..

Ex.—If a sample of bullion is 20 carats 3 gr. 5 eighths, how many troy dwt. and gr. are there in it, and what is the value of the gold in the alloy?

According to table

	dwt.	gr.	£	s.	d.
20 carats	..	..	..	..	..
3 grains	..	..	..	..	..
5 eighths	..	..	..	..	..

Answer .. .. 17 10.125     3 14 0.040

GOLD.—*Refining Bullion.* (Sage.)

(1) *Inquartation and Granulation of the Bullion.*—The gold and silver are sent from all parts of the country, consisting of bullion, amalgams, plate, &c. These are melted and assayed, and are then turned over to the melter and refiner. The bullion is again melted in a large graphite crucible, the charge being made up so that the gold shall not exceed the  $\frac{1}{3}$ , nor the copper  $\frac{1}{12}$  part of the entire weight. When the metal is melted and thoroughly mixed, it is granulated by pouring, with a peculiar rotatory motion, into a cylindrical iron tank, 3 ft. high by 3 ft. diameter, filled with cold water, and supplied with a copper colander, which, when the charge is all granulated, is raised by means of an iron crane, the water nearly all running off. It is then poured on an inclined iron table to allow the rest of the water to drain off.

(2) *Solution of the Granulations.*—The pots used for parting the alloy are made of cast iron,  $3\frac{1}{2}$  ft. and 2 ft. in diameter, by 3 ft. and 2 ft. in depth, and are set on brick fireplaces. There are 4 pots holding 160 gal., and 3 holding 50 gal. Each pot is covered with a funnel-shaped hood of sheet lead, with an opening  $1\frac{1}{2}$  ft. in diameter through which the charge is introduced, and which opens into the floor. From each of these hoods a flue leads to the  $2\frac{1}{2}$  ft. square chambers on the floor above; from the last of these a long leaden flue leads into the stack. Both chambers have platforms on which coke is laid several feet in thickness (through which the fumes pass, and are condensed), and are supplied with water sprinklers, so that a spray of water is continually cooling the atmosphere. Nitrous fumes are furnished by soda nitrate, acted upon by sulphuric acid.

About 300 lb. of the granulations are put in each of the larger pots, with about 650 lb. sulphuric acid, and 250 lb. more of the acid is gradually added during 3 hours' boiling. The resulting solution is then siphoned off into the receiving vats on the floor below. The fire being withdrawn, a partial charge of acid is added, and the gold residue is taken out by means of a perforated iron ladle, placed in two of the smaller pots, and boiled for 6 hours with 3 successive charges of about 300 lb. of acid. It is then placed in the third pot and boiled twice. The acid from the last 5 boilings is poured or run off into reservoirs on the floor, and is used again as a portion for fresh granulations. The gold is then placed in a tub, and washed once with cold, and twice with warm water: this water is poured into the washing-tub, from which, on settling, the solution is run into a large tank on the floor below.

(3) *Treatment of the Gold Residue.*—The gold is now emptied into one of the filters, washed thoroughly with warm water till it becomes "sweet," drained, boiled in 2 charges of acid for 4 hours, and again washed and sweetened. When it is desired to make very fine metal this process is repeated. It is then thoroughly drained and caked by a hydraulic press.

*Refining—continued.*

(4) *Melting and Refining the Gold.*—After the gold residue is pressed into cakes, these are placed in an oven and dried, then taken to the melting room, where they are broken up and placed in a graphite crucible, fluxed for 3–5 hours, and run into bars, varying from 997½ to 998½ thousandths in fineness.

(5) *Reduction of the Silver.*—There are for this operation 4 reducing vats, 2 concentrating vats, 8 crystallising vats, and 3 filters, 2 ft. 9 in. diameter by 19 in. deep, with a space below; 2 tanks on a high platform receive the washings from the gold. The sizes of the reducing, concentrating, and crystallising vats vary, on account of having to accommodate them to a given space. The vats and tanks are made of wood, and lined with heavy sheet lead. The reducing and concentrating vats are heated by a system of coils of lead pipe, through which steam passes. These vats are inclosed, and connect by a flue with the stack.

Before the silver sulphate is run into the vats, ingots or bars of copper are placed on end around the sides and bottoms, next to the heating coils. The solution is then run in. A sufficient amount of water, together with the weak solution obtained in washing the gold, is added to reduce the strength of the solution to 15°–25° B., which has been found to facilitate the reduction. The sulphuric acid leaving the silver to attack the copper, the silver is precipitated or deposited as metallic silver. It requires 5–6 hours' boiling to complete the reduction.

The resulting copper solution is run off through a filter into a concentrating vat. The silver remaining on the copper bars is scraped off, and the whole is put into a filter. Copper hoes and shovels are used in the handling of the silver. About 2 hours' washing with warm water is required to "sweeten" the silver. It is then put into the draining-boxes, made into cakes by a hydraulic press, and dried in an oven similar to that used for gold. When silver containing little or no gold is operated upon, 350 lb. of granulations are dissolved in one pot. With baser metals, the charge of granulations is reduced, copper requiring much more acid to dissolve it than silver.

(6) *Melting and Refining the Silver.*—The cakes are broken up, placed in graphite crucibles, and fluxed with soda nitrate, borax, bone ash, and a little soda ash. These reagents absorb the little base metal which remains, as sulphate, in washing. From 4 to 6 hours are required for fluxing. The silver is then cast into bars of 998½ to 999½ thousandths fine.

(7) *Treatment of the Sulphate of Copper.*—The solution of copper being run into the concentrating vats, is boiled until it reaches the strength of 40° B. and run into crystallising vats. In several days crystals are formed, and the mother-liquor is run into a large tank on the floor below, and thence into the carboys or tanks of purchasers. The crystals of copper sulphate are taken from the sides and bottom of the vats, drained, dissolved in water, and run

*Refining—continued.*

back into the crystallising vats at a strength of 32°–34° B. The copper sulphate again crystallises, and the mother-liquor is put back into the concentrating vats. The crystals are then taken from the vats, dried, put into barrels, and sold.

If lead is present to any extent in the bullion, it is removed by cupellation before granulating.

The consumption of copper is greatly economised in the reduction of silver by melting silver deposits free from gold and under 400 fine with the copper used for that purpose. The silver in them is thus obtained pure, without a direct parting, the copper alloy taking the place of that amount of the purchased metal that would otherwise be used.

The proceeds of the sale of copper sulphate crystals, and the liquor, nearly cover the total expense of the acid and bar copper bought.

All wood, after it becomes useless, is burnt; old, unserviceable crucibles are broken up and ground. The grains obtained from them are melted and treated as before, then put through a rough washing and amalgamation process; the resulting tailings are dried, assayed, barrelled, and sold to sweep smelters.

## GOLD MILLS.

*Specifications for 10-stamp Mill for Working Free-milling Ore.*  
(Fraser and Chalmers, Limited.)

## Breaker, Grizzly, and Feeders.

- 1 Blake eccentric pattern improved crusher,  $10 \times 7$ , all complete.
  - 1 grizzly, or ore screen, about  $4 \times 10$ , made from  $2 \times \frac{3}{4}$  iron, with washers between to make opening about 2 in., rods to connect bars, with nuts for same.
  - 2 Tulloch automatic feeders, complete, with wood frames and sheet iron hoppers.
- All necessary track iron and wood screws for track for feeders to run upon.

## Stamps.

- 1 10-stamp mill of 850 lb., each stamp of improved design, arranged to run in one battery of 10 stamps, by belt and tightener from stamp countershaft.
- 2 high mortars or batteries, each about 5000 lb. weight, planed upon bottom and for screen frames, foundation bolt-holes drilled by template, mortars arranged inside for receiving copper lining front and back.
- 2 hard wood screen frames fitted to mortars.
- 4 wrought iron keys for holding screen frames in place.
- 2 Russia iron slot punched screens, of such size as may be required.
- 10 patent stamp shoes, made from white iron, with soft grey iron necks.
- 10 dies, of best quality white iron.
- 10 heads, bored for stems and recessed for shoe stem.
- 10 stems, both ends tapered, made from best refined iron. Ends being tapered, when one end breaks the stem can be reversed and other end used.
- 10 tappets with wrought jib and steel keys, all properly fitted to place.
- 10 cams (5 right and 5 left hand) fitted to cam shaft with steel keys, all properly marked to place, to give proper drop.
- 1 heavy hammered iron cam shaft turned full length and key-seated for pulley and cams.
- 2 wrought collars and steel set screws, fitted to cam shaft.
- 3 heavy corner cam shaft boxes, babbitted and bored, planed upon back, and furnished with bolts and caps.
- 2 Jack shafts, not turned.
- 4 Jack shaft boxes.

*Specifications—continued.*

- 10 iron sockets for wood levers, lined with leather.
- 10 wood levers or finger pieces, for holding up stamps, fitted to sockets.
- 1 pair of double sleeve flanges for wood pulleys, turned and fitted together, with wood work built up, hub key seated, wood work turned up and painted, and securely bolted through flanges.
- All bolts, rods, nuts, and washers, for 10-stamp frame work complete, including all holding-down bolts and washers for mortars.
- 1 complete set of hardwood guide boxes, all worked out for stamp stems, with all guide bolts, nuts and washers.
- 2 pieces of rubber packing,  $\frac{1}{4}$  in. thick, for top of mortar blocks, for mortars to rest upon.

**Water Pipes.**

- 1 complete set of water pipes for 10 stamps proper, with valves and fittings ready for connection with main supply, also hose for washing copper plates in front of mill.

**Copper.**

- 2 sheets of pure L. S. copper, 96 in. by width of mortar by  $\frac{1}{8}$  in., for tables in front of mill.
- 2 sheets of pure L. S. copper,  $\frac{3}{16}$  in., for mortars inside, all fitted, front and back.
- 2 sheets of pure L. S. copper,  $\frac{3}{16}$  in., for mortars inside, all fitted, sides.

**Building Bolts.**

- 1 complete set of building bolts, rods, nuts, and washers, for frame of building, and also for ore bins.

**Tighteners.**

- 1 stamp tightener for stamp belt, complete, with wood frame, rack, pinion, hand wheels, dogs, etc.
- 1 breaker tightener for breaker belts, complete, with swinging frame, chain, shaft, and hand wheel.
- 1 main tightener for engine belt, complete, with wood frame, rack, pinion, hand wheel, dogs, etc.

**Shafting, Pulleys, and Belting.**

- 1 main line turned shaft,  $3\frac{3}{4}$  in. dia. by 11 ft. 3 in.
- 3 pillow blocks for  $3\frac{3}{4}$  in. shaft.
- 1 pulley, 32 in. by 15 in., to drive stamps.
- 1 pulley, 42 in. by 14 in., on engine shaft, to drive main line shaft.
- All necessary bolts for pillow blocks.
- All necessary collars and set screws.
- 1 turned shaft,  $2\frac{3}{8}$  in. by 7 ft. 6 in., for driving crusher.
- 2 pillow blocks for  $2\frac{3}{8}$  in. shaft.

*Specifications—continued.*

- 1 pulley, 60 in. by 14 in., to receive power from engine.
- 1 pulley, 36 in. by 10 in., to drive crusher countershaft.
- 1 pulley, 24 in. by 10 in., on crusher countershaft.
- 1 pulley, 40 in. by 8 in., to drive crusher.
- All necessary bolts for pillow blocks.
- All necessary collars and steel set screws.
- 1 rubber belt, 45 ft. by 14 in., 4-ply, for battery.
- 1 belt, 49 ft. by 14 in. by 4-ply, for engine.
- 1 belt, 70 ft. by 10 in. by 4-ply, for crusher countershaft.
- 1 belt, 47 ft. by 7 in. by 4-ply, for crusher.
- 1 belt, 27 ft. by 5 in. by 3-ply, for engine belt feed pump.
- 1 hide of lace leather.

**Amalgam Safe.**

- 1 amalgam safe and strainer, with padlock.

**Retort and Bullion Furnace.**

- 1 retort, complete, with cover, wedge and condenser.
- 1 16-in. bullion furnace, with all iron work, one set of crucible tongs, 2 gold bullion moulds, and one set of steel letters for stamping bullion.

**Overhead Crawl and Block.**

- 1 overhead carriage crawl and track iron, with wood screws for same.
- 1 one-ton differential pulley block.

**Engine.**

- 1 Fraser and Chalmers' stationary slide valve steam engine, cylinder 9 in. bore by 14 in. stroke, complete, as per specifications attached. [This engine has power for driving the above described machinery only, together with two or four frue vanners if required.]

**Boiler.**

- 1 Fraser and Chalmers' tubular steam boiler, 40 in. dia. by 10 ft. long, complete with all fixtures and trimmings, breeching and smoke stack, as per our standard specifications attached.

**Feed Pump, Heater, and Pipes.**

- 1 belt feed pump, 2 by 3.
- 1 heater, with pipe coil.
- All pipes, valves, and fittings for steam, water, and exhaust to make power complete, as per plans we furnish.
- Total approximate weight 60,000 lb.

*N.B.*—To the above on most gold ores must be added for concentrating the sulphurets eight frue vanning machines, with amalgam savers and all necessary shafting, pulleys, and belts, for driving the same. This will increase the weight of mill to say 85,000 lb.



## SILVER MILLS.

*Specifications for 10-stamp Wet Crushing Mill.* (Fraser and  
Chalmers, Limited.)

## Crusher.

- 1 10 by 7 in. Blake crusher, to be furnished complete ready to run when set in place.
- 1 duplicate set of jaw plates for above crusher.

## Grizzly.

- 1 grizzly or ore screen for relieving breaker, size 4 by 10 ft. complete.

## Automatic Feeders.

- 2 Tulloch improved automatic feeders complete, with wood frames and sheet iron hoppers. All necessary track iron, punched and countersunk with wood screws for laying same for feeders to operate upon.

## Stamps.

- 1 10-stamp mill of improved design, each stamp weighing 850 lb., arranged to run in one battery of 10 stamps by belt and tightener from stamp countershaft, complete in detail as below.
- 2 high mortars or batteries, double discharge, all to be complete with screen frame and faces planed; also planed upon bottom for resting upon foundation. The bolt holes drilled by template
- 4 hard wood screen frames fitted to mortars.
- 8 wrought iron keys for holding screen frame in place.
- 4 Russia iron slot punched screens, of such size as may be required.
- 10 patent stamp shoes, made from white iron, with soft grey iron necks.
- 10 stamp dies of best quality white iron.
- 10 stamp heads, bored for stems, and recessed for shoe stem.
- 10 stamp stems, made from extra fine iron, both ends tapered; when one end breaks the stem can be reversed and other end used.
- 10 stamp tappets, with wrought iron jib and steel keys all properly fitted to place. Tappets faced on ends.
- 10 cams (5 right and 5 left hand) fitted to cam shaft with steel keys all properly marked to place to give proper drop.
- 1 heavy hammered iron cam shaft, turned full length, key-seated for cams and driving pulley.
- 2 wrought iron collars with steel set screws, fitted to cam shaft.
- 3 heavy cam shaft boxes, babbitted, hammered and bored, planed upon buck, and furnished with bolts and caps.

*Specifications—continued.*

- 2 Jack shafts, not turned.
- 4 chairs or sockets for jack shafts to rest in.
- 10 iron sockets for wood levers, lined with leather, for stamp holders.
- 10 wood levers or finger pieces for holding up stamps, fitted to sockets.
- 1 pair of double sleeve flanges for wood pulley, turned and fitted together with wood work built up between, hub key-seated, wood work turned up and painted and securely bolted through flanges, to be fitted with steel key, properly marked to place.
- All necessary bolts, rods, nuts, and washers for 10-stamp framework complete, including all holding-down bolts and washers for mortars.
- 1 complete set of hard wood guide boxes, all worked out for stamp stems, with all guide bolts, nuts, and washers.
- 2 pieces of rubber packing  $\frac{1}{4}$  in. thick, for top of mortar blocks for mortars to rest upon.

*Water Pipes.*

- 1 complete set of water pipes for 10-stamp mill, including all valves, water cocks, and fittings for supplying each stamp with water. Connection to be prepared to receive water from main supply.

*Memorandum.*

The piping actually furnished does not include sufficient to connect with main supply, as quantity cannot be determined upon owing to not knowing location of water tank.

*Combination Pans.*

- 4 improved combination amalgamating pans, each 5 ft. diameter, with wood staves, to be furnished with upright cone in bottom, upright spindle fitted with separate steel toe, 2 hand wheels and screw on top of spindle for raising muller nut for screw, driver sleeves, driver arms separate from sleeves and bolted to same muller plate. 8 cast iron shoes and 8 cast iron dies to each pan, wrought iron bands and lugs for staves, step box fitted on plate, which also carries one bearing of countershaft, step box fitted with steel buttons and bushings, countershaft, driving pulley, out end bearing for shaft. All bolts for boxes for bolting to framework.

*Settlers.*

- 2 8-ft. combination settlers complete, the same in detail as pans enumerated above, with the exception of shoes and dies. Wooden shoes to be furnished with settlers.

*Clean-up Pan.*

- 1 48-in. clean-up pan, all complete as usually furnished, the same as pans detailed above,

*Specifications—continued.***Retort.**

- 1 12-in. silver retort, all complete, with cover bar and hand screw for holding cover in place, carriers, fire front complete, with fire door and liners, dead plate, back bearer, double grate bars, condensing pipe, cast iron ash pan, all necessary wall binders and rods for bracing brick work.
- 1 set of castings for 16-in. bullion furnace complete, including top cover, bearing bars, grate bars, anchor bolts, &c.
- 6 assorted black lead crucibles and covers.
- 1 set of trays or cups for holding amalgam.
- 1 pair crucible tongs.
- 1 set of bullion moulds, three in number, assorted sizes.
- 1 set of steel numbers for stamping bullion bars.
- 1 iron floor plate, punched and countersunk, with wood screws for laying same for retort room floor.
- 1 smoke stack for retort bullion furnace, of suitable diameter and length, with base plate and guys for staying stack.

**Quicksilver System.**

- 1 complete quicksilver elevator, with rubber belt, Russia iron cups, and all fixtures and fittings required for making elevator complete, including :
  - 1 upper and lower quicksilver tank.
  - 2 quicksilver charging pots.
- All pipes, iron cocks, and fittings for the complete quicksilver circulating system that may be required to make same complete.

**Overhead Crawls.**

- 3 overhead carriage crawls complete.
- 2 two-ton differential pulley blocks.
- 1 one-ton differential pulley block.
- All necessary track iron, punched and countersunk, with wood screws for laying same for overhead crawls to run upon.

**Piping.**

- All necessary water pipes, valves and fittings for the complete mill, for supplying pans and settlers with the necessary steam and water, ready to receive connection with main supply.

**Tighteners.**

- 1 crusher tightener complete.
- 4 pan tighteners complete.
- 1 stamp tightener complete.

**Shafting, Pulleys, and Belting.**

- All necessary shafting, pulleys, boxes and belting for driving all of the above described machinery in accordance with our drawings.
- All the belting throughout the entire mill to be Boston Belting Company's best brand.

*Specifications—continued.*

All pulleys to be turned, faced, and balanced, pillow blocks to be planed upon bottom and lined with best babbitt metal and bored out, couplings to be fitted to shaft with keys, to be turned and faced, all bolts to be furnished for all bearings, all key-seats to be cut in shafts so as not to be in bearings.

**Building Bolts.**

All necessary bolts, rods, nuts, and washers for the complete framework of mill building in accordance with our drawings as usually furnished.

**Engine.**

1 Fraser and Chalmers' slide valve engine with Corliss style frame, size 14 by 24 in., all complete in detail as per printed specifications attached.

**Boilers.**

2 Fraser and Chalmers' tubular steam boilers, each 48 in. diam. by 14 ft. long, complete in detail as per printed specifications attached.

**Heater.**

1 24-in. tubular steam heater complete, including galvanised iron pipe for passing through roof.

1 No. 3 Knowles' steam boiler feed pump.

All necessary pipe connections for properly connecting engine, boiler, heater and feed pump.

Total Approximate Weight, 175,000 lb.

*Specifications for 10-stamp Dry-crushing Chloridising Mill.*

(Fraser and Chalmers, Limited.)

**Boilers.**

2 Fraser & Chalmers' tubular steam boilers, each 48 in. diam. by 14 ft. long, all complete as per specifications attached.

1 Fraser & Chalmers' Corliss steam engine, size 14 by 42 in., all complete in detail as per specifications attached. Crank shaft to be fitted with suitable size clutch coupling for coupling to pan line shaft.

1 Fraser & Chalmers' tubular steam heater, 24 in. diam., all complete in every respect.

1 No. 4 Knowles' boiler feed pump for feeding boilers with water.

All necessary steam, exhaust, and feed pipes to properly connect boilers, engine, heater, and feed pump.

**Grizzly.**

1 Grizzly or ore screen for relieving crusher, size 4 by 10 ft.; made from 2 by 1 in. iron with washers between. Rods to connect bars with nuts for same.

*Specifications—continued.***Crusher.**

110 by 7 Blake crusher, all complete ready to run when set in place.

**Automatic Feeders.**

2 Tulloch automatic ore feeders for stamps, with wood frames and sheet iron hoppers.

All necessary track iron, punched and countersunk, with wood screws for laying same for feeders to operate upon.

**Stamps.**

- 1 10-stamp mill of improved design, each stamp weighing 900 lb., arranged to run in one battery of 10 stamps by belt and tightener from stamp countershaft, all complete in detail as below :—
- 2 high mortars, double discharge, planed upon bottom, and faced for screen frames. Foundation bolt holes drilled by template.
- 4 wood screen frames, fitted to mortars.
- 8 wrought iron keys for holding screen frames in place.
- 4 brass wire cloth screens of such size as may be required.
- 10 patent stamp shoes.
- 10 patent stamp dies.
- 10 stamp heads, bored for stems and recessed for shoe stem.
- 10 stamp stems, made from extra refined iron, both ends tapered; ends being tapered, when one end breaks the stem can be reversed and other end used.
- 10 tappets with wrought iron jibs and steel keys, all properly fitted to place. Faces turned.
- 10 cams (one-half right and one-half left hand), fitted to cam shaft with steel keys all properly marked to place to give proper drop.
- 1 heavy hammered iron cam shaft, turned full length and key-seated for pulley and cams.
- 2 wrought iron collars with steel set screws, fitted to cam shaft.
- 3 heavy corner cam shaft boxes, babbitted and bored, planed upon back and bottom, and furnished with bolts and caps. Boxes to be babbitted with best composition metal.
- 2 Jack shafts, not turned.
- 4 Jack shaft boxes.
- 10 iron sockets for wood levers, lined with leather.
- 10 wood levers or finger pieces for holding up stamps, fitted to sockets.
- 1 pair of double sleeve flanges for wood pulley, turned and fitted together with wood work built up between, hubs key-seated, wood work turned up, painted and securely bolted through flanges.

*Specifications—continued.*

All necessary bolts, rods, nuts, and washers for 10 stamp frame work complete, including all holding-down bolts and washers for mortars.

- 1 complete set of hard wood guide boxes for 10 stamps, all worked out for stamp stems, with all guide bolts, nuts, and washers.
- 4 sheets of rubber packing, each  $\frac{1}{4}$  in. thick, for top of mortar blocks for mortars to rest upon.

**Roasting Furnace.**

- 1 improved Howell-White roasting furnace, 52 in. diam., at small end, 62 in. diam. at large end, by 27 ft. long, made in 8 sections,  $\frac{3}{8}$  in. thick; sections faced and bolted together with  $\frac{5}{8}$  in. bolts, with all fixtures and fittings necessary to make the furnace complete in every respect as usually furnished, including carrying rollers, gearing, pulleys, vertical shafting, fire front, grate bars, &c.
- 1 smoke stack 42 in. diameter by 60 ft. long.
- 400 ft.  $\frac{3}{8}$  in. guy rope.
- 1 base plate for stack.
- 1 set of fire tools for the above furnace.

**Revolving Dryer.**

- 1 revolving dryer made of cast iron, 44 in. diam. at large end, 36 $\frac{1}{2}$  in. diam. at small end, by 18 ft. long, made in sections, all properly turned and faced, drilled and bolted together with  $\frac{5}{8}$  in. bolts; dryer to be furnished complete with fire front, grate bars, bearings, binding bars, tie rods, gearing, boxes, truck wheels, sole plates for bearings, countershafts, tight and loose pulleys, and everything necessary to make dryer complete in all respects.
- 1 smoke stack for dryer, 24 in. diam. by 50 ft. long.
- 300 ft. of  $\frac{5}{8}$  in. galvanised iron guy rope.
- 1 cast iron base plate for smoke stack.

**Feeder for Dryer.**

- 1 Tulloch ore feeder for feeding dryer from ore bins, to be furnished complete with countershaft and pulleys.
- All necessary track iron, punched and countersunk, with wood screws for laying same for feeder to operate upon.

**Sheet Iron Shute.**

- 1 sheet-iron shute from dryer to self-feeders at stamps.

**Pans.**

- 4 improved combination amalgamating pans, each 5 ft. diam., with wood staves, to be furnished with upright cone in bottom, upright spindle, fitted with separate steel toe, 2 hand wheels and screw on top of spindle for raising muller nut for screw

*Specifications—continued.*

driver sleeves, driver arms separate from sleeves and bolted to same, muller plate, 8 cast iron shoes and 8 cast iron dies to each pan, wrought iron bands and lugs for staves, step box fitted on plate, which also carries one bearing of countershaft; step box to be fitted with steel buttons and bushings, countershaft, driving pulley, out end bearing for shaft, all bolts for boxes and for bolting to framework.

**Settlers.**

- 2 8-ft. improved combination settlers, with wood staves, to be complete in every respect as pans above, the enumeration being the same excepting shoes and dies, wooden shoes and dies being furnished for the settlers.

**Clean-up Pan.**

- 1 30-in. clean-up pan with iron sides, complete in every respect. Fitted with cone pulley for changing speed.

**Ore Bin Gate.**

- 1 ore gate complete for ore bins, with rack, hand wheel, slide and plate.

**Ore Gate for Dryer Pit.**

- 1 ore gate complete for dryer pit, with rack, hand wheel, slide and plate.

**Retort.**

- 1 14-in. silver retort complete, including cover, bar and nut, screw for holding cover in place, 3 retort carriers, fire fronts complete, with doors and liners, dead plate, back bearers, 2 double grate bars, condensing pipe, cast iron ash pan, wall binders and rods for bracing brick work, and all necessary fittings required for the complete erection.

**Bullion Furnace.**

- 1 set of castings for 16 in. bullion furnace top, including cover, bearing bars, grate bars, anchor bolts, and all fixtures and fittings belonging thereto.
- 6 assorted black-lead crucibles and covers.
- 1 set of trays or cups for holding amalgam.
- 1 pair of crucible tongs.
- 2 1000-ounce bullion moulds.
- 1 500-ounce bullion mould.
- 1 set of steel numbers for stamping bullion bars.
- 1 smoke stack for retort bullion furnace, 20 in. diameter by 30 ft. long, with base plate and guy ropes for staying same.
- 1 set of iron floor plates for retort room floor, with all necessary screws for laying same.

**Overhead Crawls.**

- 3 overhead carriage crawls complete.

*Specifications—continued.***Pulley Blocks.**

- 2 two-ton Yale & Towne differential pulley blocks, with endless chain.
- 1 one-ton Yale & Towne differential pulley block, with endless chain.
- 160 ft.  $1\frac{1}{2}$  by  $\frac{1}{4}$  in. track iron, punched and countersunk, with wood screws for laying same.

**Battery Conveyors.**

- 2 battery conveyors with 8 in. flights, each conveyor 16 ft. long, to be furnished complete with shafts, pulleys, pillow blocks, and collars.

**Roaster Conveyors.**

- 3 roaster conveyors with 10 in. flights, each conveyor 16 ft. long, to be furnished complete with pulley, chain, wheels, and bearings.

**QUICKSILVER SYSTEM.****Elevator.**

- 1 complete quicksilver elevator, with rubber belts, Russia iron cups, and all fixtures and fittings required for making elevator complete in every respect.
- 1 each upper and lower quicksilver tanks.
- 2 quicksilver charging pots for pans, size 12 by 12 in.
- 2 amalgam safes with strainers complete, with padlocks and duplicate keys, with all necessary fittings and fixtures to make same complete.
- 1 amalgam car, complete.
- 120 ft. one-half round track iron, with spikes for laying same for car to operate upon.

**Quicksilver Piping.**

- All pipes, iron cocks and fittings for the complete quicksilver circulation system that may be required in accordance with our drawings and necessary to make system complete in every detail.

**Tighteners.**

- 1 main tightener for 16-in. belt, to be furnished complete with pulley, boxes, screws, hand wheel, nuts, and frames.
- 4 pan tighteners for 12-in. belt, with improved angle iron frames, shafts, pulleys, wrought iron yokes, chains, upright shafts, step and guide boxes, hand wheels, and plates.
- 1 crusher tightener for 7-in. belt, with pulley, boxes, shaft, step, pinion, ratchet, plate, dog and hand wheel, rack, wood frame, and bolts.



*Specifications--continued.***Dust Pipes.**

- 1 complete set of galvanised iron dust pipes for removing dust from battery.

**Exhaust Fan.**

- 1 Sturtevant monogram exhaust fan of suitable size, with countershaft complete for above dust pipes.

**Water Pipes.**

All water pipes, valves, and fittings, necessary for the complete mill, for supplying pans and settlers with necessary steam and water, ready for receiving connection with main water supply, but not including pipe for connecting with tank or mill supply.

- 1 hot ore car, complete, made entirely of iron.
- 2  $\frac{1}{2}$ -ton scoop ore cars, with iron bodies, 18 inch gauge.
- 1 set of iron work for transversal car, with axles and wheels.
- 180 ft. of 12-lb. T-rail, with spikes and joints for laying same for cars to run upon.
- All necessary bolts, rods, nuts, and washers for the complete frame work of mill building, in accordance with our drawings as usually furnished by us.
- 7 complete sets of ore gates for pulp bins, with levers, slides, and plates.

**Elevators.**

- 1 ore elevator complete, comprising:
  - 1 shaft,  $2\frac{1}{2}$  by 5 ft.
  - 2 pillow blocks,  $2\frac{1}{2}$  in.
  - 2 pulleys, 36 by  $8\frac{1}{2}$  in.
  - 1 shaft,  $2\frac{7}{16}$  in. by 2 ft. 6 in.
  - 2 pillow blocks,  $2\frac{7}{16}$  in.
  - 1 pulley, 16 in. by  $8\frac{1}{2}$  in.
- All necessary collars, bolts, and steel set screws.
- 88 7-in. Duc's heavy elevator buckets.
- 176 bolts for attaching buckets to belt.
- 125 ft. 8 in. 5-ply endless rubber belt for elevator, belt punched with holes for attaching buckets.

**Shafting, Pulleys, and Boxes.**

- All necessary shafting, pulleys, boxes and belting for driving all of the above described machinery, in accordance with our drawings.
- An assortment of copper rivets and burrs.

Total approximate weight, 265,000 lb.

*Specifications—continued.***Addenda.****Smoke Stacks.**

In the above estimates we have included smoke stacks for both roasting furnace and revolving dryer. If, however, it is desired to build stacks of brick, omit the smoke stacks we have included. Brick stacks are only practicable in some localities, and it will be found that iron stacks such as we have included are the cheapest, being much more easy to erect. Stacks rolled, punched, and shipped K. D., in crates when desired ; usually shipped in riveted sections of 20 ft.

**Fire-brick for Roasting Furnace.**

For lining the 60-in. Howell-White roasting furnace, 3040 special shaped fire-bricks are required. Sometimes this fire-brick can be purchased near the mines. If, however, it is desired to have this brick shipped with the machinery, we give below the cost and weight.

3040 special shaped fire-bricks, weight about 36,500 lb., cost about 310 dols., F.O.B. cars, Chicago.

For this amount of fire-brick, you would require about two barrels of fire-clay, each costing 4 dols., weighing 500 lb. each.

The mill, as covered by specifications, is complete and automatic.

We recommend the use of patent sectional stamp guides instead of ordering guides as specified above.

## GOLD AND SILVER MILLS.

*Combination Process.* (Fraser and Chalmers, Limited.)

In many so-called free milling ores of silver, or silver and gold combined, there are small quantities of sulphides of the baser metals, not sufficient in quantity or value to make the ore suitable for roasting, yet preventing a high extraction by free milling, besides increasing the cost of the same. Such ores are most economically treated by a combined process of concentration and amalgamation; the usual method being to stamp wet—over copper plates if gold is present—concentrate on frue vanners, and then amalgamate the tailings in pans, preferably by the Boss continuous system. The effect of this treatment is as follows:—the free gold is caught at once on the copper plates, the sulphurets are saved as a rich product, by the concentrators for subsequent treatment, and the residue is in good shape then for amalgamation in pans. The benefits to amalgamation, by first abstracting the sulphurets, are evident as shown—

- (a) Grinding in the pans is lessened or entirely dispensed with, so decreasing wear of castings and fuel consumption.
- (b) Loss of quicksilver is decreased.
- (c) Coarser crushing, and therefore increased capacity of stamps, becomes possible.
- (d) Bullion of a higher grade is obtained.
- (e) The total percentage of extraction is raised.

All these advantages are quite obvious, and may, together constitute the difference between a good profit and an actual loss, in working some low grade ores. The Montana Company (Ltd.), by the adoption of this process, obtained a total increased saving over simple pan amalgamation, of from 8 dols. to 10 dols. per ton, decreased the loss of quicksilver by  $\frac{1}{2}$  lb. per ton of ore, and brought the grade of the bullion from 500 fine up to 900 fine.

The cost of this process is from 3 dols. to 7 dols. per ton, saving from 75 to 85 per cent.

## COPPER SMELTING PLANT.

*Hardware Tools and Miscellaneous Supplies required for a 30-ton Plant  
(Fraser and Chalmers, Limited.)*

## HARDWARE.

- |  |  |
|--|--|
| 4 iron wheelbarrows.   | 2 No. 10 scoop shovels.  |
| 6 L. H. square point shovels.  | 1 14-in. steel rake.   |
| 1 mason's trowel.  | 1 each stone hammers 8 and 10 lb.                                  |
| 1 No. 7 26-in. hand saw.   | 1 No. 3 claw hatchet.  |
| 1 nail hammer, No. 3.  | 1 ratchet brace.   |
| 1 set Jennings' bitts.   | 1 each fore and jack plane.  |
| 1 set framing chisels.   | 1 No. 2 machinist B. P. hammer.                                    |
| 1 axe and handle.  | 1 doz. sledge handles.   |
| $\frac{1}{2}$ doz. each axe and hammer handles.  | 2 charcoal forks, short handle.                                    |
| $\frac{1}{4}$ doz. each $4\frac{1}{2}$ -in. taper, 12-in. $\frac{1}{2}$ round bast. files.                             | 1 60-lb. grindstone.   |
| $\frac{1}{4}$ doz. 12-in. flat bast. files.  | 1 set grindstone fixtures.   |
| 10 lb. assd. $\frac{1}{4}$ to $\frac{3}{4}$ -in. wrought washers.  | 1 each single and double pat. blocks.                              |
| 150 ft. 1-in. diam. rope.  | 2 lb. copper rivets and burrs, $\frac{3}{4}$ -in. No. 5.           |
| 1 12-in. Coe's black wench.  | 1 ratchet drill stock.   |
| 1 each twist drill $\frac{1}{4}$ , $\frac{5}{16}$ , $\frac{3}{8}$ , $\frac{1}{2}$ , $\frac{5}{8}$ , $\frac{3}{4}$ -in. | 1 N. Y. B. stock and dies.   |
| 5 steel sledges, two 7-lb., two 8-lb., one 10-lb.  | 1 spirit level.  |
| 1 steel square.  | 12 bars oct. steel—  |
| 1 each iron stopping bars, $\frac{3}{4}$ , 1, $1\frac{1}{2}$ -in. by 6 ft.   | 4 2 3 3  |
| 100 lb. assd. machine bolts, $\frac{1}{2}$ , $\frac{5}{8}$ , and $\frac{3}{4}$ -in.                                    | 6 each ends $\frac{3}{4}$ , $\frac{7}{8}$ , 1, $1\frac{1}{4}$ -in. |

## BLACKSMITH'S OUTFIT.

- |  |   |
|--|---|
| 1 No. 1 riveting hammer.                                       | 2 hot cutters.                                  |
| 1 No. 3 blk. striking hammer.                                  | 2 cold cutters.                                 |
| 2 solid steel sledges.   | 2 rd. punches, $\frac{3}{8}$ by $\frac{1}{2}$ . |
| 1 swage block.   | 2 gouge chisels.                                |
| 4 P. W. anvil.   | 1 $\frac{1}{2}$ round heading tool.             |
| 1 G. H. tuyere.  | 1 $\frac{1}{2}$ square heading tool.            |
| 1 set top and bottom swages, $\frac{3}{8}$ to $1\frac{1}{2}$ . | 2 Hardies.                                      |
| 2 square flatters.   | 6 pair assorted tongs.                          |
| 2 round flatters.  | 1 P. W. vice.                                   |
| set hammer.  | 1 36-in. extra long bellows.                    |

Approximate cost, 90 dols.

## PIPE FITTINGS.

- |   |   |
|---|---|
| 1 each pipe stock and dies,<br>Nos. 1 and 2.  | 2 1-in. hose bibs, S. S. & S.   |
| 1 pair each Brown's tongs,<br>Nos. 2 and 4.   | 1 each pipe cutters, Nos. 1<br>and 2.   |
| each unions $\frac{1}{2}$ , $\frac{3}{4}$ , 1, $1\frac{1}{4}$ , $1\frac{1}{2}$ ,<br>and two 2-in.     | 2 each extra cutters, Nos. 1<br>and 2.  |
| 6 each tees $\frac{1}{2}$ , $\frac{3}{4}$ , 1, $1\frac{1}{4}$ , $1\frac{1}{2}$ , and<br>two 2-in.     | 6 couplings, $\frac{1}{2}$ , $\frac{3}{4}$ , 1, $1\frac{1}{4}$ , $1\frac{1}{2}$ , and<br>four 2-in. |
| 6 each nipples, $\frac{1}{2}$ , $\frac{3}{4}$ , 1, $1\frac{1}{4}$ , $1\frac{1}{2}$ ,<br>and two 2-in. | 6 ells, $\frac{1}{2}$ , $\frac{3}{4}$ , 1, $1\frac{1}{4}$ , $1\frac{1}{2}$ , and two<br>2-in.       |
|   | 1 comb. pipe vice.  |

Approximate cost, 100 dols.

## RUBBER GOODS.

- |  |   |
|--|---|
| 50 ft. 1-in. by 4 ply hose in 2<br>pieces.                               | 10 lb. hemp packing.  |
| 1 yd. $\frac{1}{4}$ -in sheet packing.                                   | 1 1-in. nozzle and couplings.                                     |
| 2 coils each $\frac{3}{8}$ , $\frac{1}{2}$ -in. tucks<br>square packing. | 2 yd. each $\frac{1}{8}$ , $\frac{1}{10}$ -in. sheet pack-<br>ing |
|  | 1 side lace leather.  |

Approximate cost, 60 dols.

## MISCELLANEOUS.

- |   |   |
|---|---|
| 2 soldering irons.  | 1 1-gal. oil can.   |
| 3 bars solder.  | 1 lamp filler can.  |
| 6 spring oilers.  | 1 keg white lead, in oil.   |
| 1 keg dry red lead.   | 1 14-in. tin head-light.  |
| 5 10 by 14 square lanterns,<br>with reflectors.             | 1 $\frac{1}{4}$ -in. mesh sand screen,<br>with frame.               |
| 6 tubular lanterns.   | 2 each sheet iron, Nos. 10<br>and 16.                               |
| 3 tubular lantern globes,<br>extra.                         | 1 No. 2 warehouse truck.  |
| 12 lantern glasses.   | 100 square fire brick.  |
| 12 lantern chimneys.  | 50 key fire brick.  |
| 4 doz. wicks.   | 200 wedge fire brick.   |
| 1 6-in. round clock.  | 20 gal. valvoline, in $\frac{2}{5}$ -cases,<br>for engine cylinder. |
| 4 bbls. fire clay.  | 40 gal. extra W. S. lard oil,<br>in $\frac{2}{5}$ -cases.           |
| 4 bbls. fire sand.  | $\frac{1}{2}$ doz. zinc oilers.                                     |
| 2 1000-lb. D. L. platform<br>scales, Howe's broad<br>wheel. | 1 long spout oiler.   |

Approximate cost, 340 dols.

## ORES, TREATMENT OF.

The following synopsis embraces the recognised methods of dealing with various ores, two or more methods being sometimes adopted in combination.

If free *gold* can be panned out and no sulphurets = Free gold milling.

Free *gold* found, but also sulphurets, which on being panned out, after free gold is separated, assay sufficiently well to pay for treatment after = Free gold milling, with vanning machines for tailings; chlorination, or smelting for product.

Free *gold* in small quantities, but much *silver* present in sulphurets = Roasting milling; or free gold milling, vanners, and smelting; or copper plates, vanners, and pans.

Chloride of *silver* ores, and decomposed silver vein outcrops, over 6 oz. per ton = Free silver milling.

*Silver* ores consisting of part chloride or decomposed, and part silver-bearing sulphurets = Free silver milling, vanners and smelting; or if grade of ore is high = Roasting milling.

*Silver* ore with base metal sulphurets, if low grade = Fine concentration and smelting; if higher grade = Roasting milling.

Low grade *silver* ores, with gray *copper*, *tellurides*, ruby, brittle, or native *silver* = Fine concentration and smelting.

Heavily mineralised ores of *lead*, *copper*, *zinc*, often carrying *silver* = Coarse concentration and smelting.

Lightly mineralised ores of *lead*, *tin*, *copper*, *zinc* = Fine concentration and smelting.

Carbonate or oxide of *lead* or *copper* = Smelting.

Solid *galena* ores = Smelting, either after simple hand selection, or hand selection and coarse concentration on rejected ore.

Metallic *copper* ores = Stamping, with coarse concentration, and melting to ingot.

*Antimony* ores = Hand-picking, coarse or fine concentration, and smelting for metal.

*Zinc-blende* and *zinc-carbonates* = Coarse or fine concentration, and reduction by a zinc smelting process.

*Tin* ores = Fine concentration, roasting, and smelting.

*Copper* pyrites and copper glance = Hand-picking, coarse or fine concentration, partial roasting and matting; or if on seaboard, shipment of selected and concentrated product to refineries; or if low grade, sometimes lixiviation for copper and silver.

Heavy *iron* pyrites, carrying *gold* = Chlorination process; or roasting and intermixture with smelting ores.

## COAL CLEANING.

Table 122.—COAL CLEANING: *Cost.*

Makers.	Where in Operation.	Pence per Ton.
Bell, Wishaw .. .. .	Tannochside .. .. .	4·6
McCulloch .. .. .	Devon .. .. .	4·48
Carlton Iron Co. .. .. .	East Howle .. .. .	1·24
Bell & Ramsay .. .. .	Tursdale .. .. .	1·27
Bolchow, Vaughan, & Co. .. .. .	Binchester .. .. .	1·48
Coppée .. .. .	Dowlais Co. .. .. .	5·3
Sheppard .. .. .	Kinnell Iron Co. .. .. .	2·5
Carron Co. .. .. .	Carron .. .. .	7·6

Table 123.—COAL CLEANING: *Results and Cost.*

Name of Washer.	Total Cost.	Quantity of Water used per Ton.	Loss per Ton in Dross left in Rubbish, calculated at 2s. per Ton.	Cost of Washing per Ton.	Cost per Ton of Dross to Redeem Capital at 10 per cent., 30,000 Tons per annum.	Total Cost of Washing per Ton.
	£	gal.	d.	d.	d.	d.
Bash Machine—						
Bell & Sons, at Tannochside	500	200	1·7	2½	·4	2·9
McCulloch's, at Devon ..	600	200	say 1·0	3	·48	3·48
Trough—						
East Howle .. .. .	300	350 to	nil	1	·24	1·24
Tursdale .. .. .	250	400	·7	1	·20	1·20
Rotary—						
Robinson .. .. .	250	30	·2	1	·20	1·20
Felspar—						
Coppée .. .. .	2500	300	·3	3	2·00	5·30
Sheppard .. .. .	500	..	·1	2	·4	2·40
Carron—						
Experimental .. .. .	..	..	·4	7	..	7·40

\* Labour, cost, and depreciation only included, power and other establishment charges not included.

Table 124.—COAL CLEANING: Results.

Name of Colliery.	Name of Washing Machine.	Rubbish in Dross Coal previous to Washing.	Rubbish left in Dross Coal.	Quantity removed by Washing Operation.	Coal in Rubbish removed by Washing.	Total Rubbish and Coal taken out in Operation of Washing.	Percent-ages of Total Rubbish taken out in Washing.	Weight of Dross lost as being mixed with Rubbish taken out in Operation of Washing on every 100 Tons Washed.	Weight of Rubbish left in every 100 Tons of Washed Dross.
		per cent.	per cent.	per cent.	per cent.	per cent.	per cent.	tons cwt. qr.	tons cwt. qr.
Dowlais ..	Coppée ..	22·64	3·24	19·40	5·70	25·10	85·69	1 3 2	0 16 0
East Howle	Ramsay trough ..	25·35	13·51	11·84	trace	11·84	46·80	trace	1 11 3
Binchester	Robinson ..	27·23	19·24	8·99	3·80	12·79	33·00	0 9 2	2 6 2
Tursdale ..	Bell & Ramsay trough ..	13·84	3·40	10·44	13·38	23·82	75·44	3 3 2	0 16 0
Kinnell ..	Sheppard ..	15·37	9·06	6·31	4·25	10·56	39·90	0 8 3	0 19 0
Devon ..	McCulloch ..	39·26	..	..	38·13	..	..	..	..
Carron ..	Trough ..	14·32	4·45	9·87	9·14	19·01	68·92	1 14 2	0 16 3
Woodend ..	.. ..	20·00	11·00	9·00	23·00	32·00	45·00	7 6 0	..



Table 125.—COAL CLEANING: *Statements Contrasting Practice at several Collieries.*  
I. *Dry Cleaning.*

Name.	Speed per Minute of Picking Bands.	Number of Belts.	Total Length of Bands.	Total Length of Band available for Operating on.	Capacity.	Vibration of Scr-ens per Minute.	Inclination.
Barrow .. ..	ft. 30 to 35	..	ft. ..	ft. ..	1200 to 1500 tons daily	80 to 100	1 in 2.4
Aldwarke Main	40 " 50	3	180	180	600 tons in 8 hours ..	106	1 " 3
Nuntery Main	60	3	120	120	.. .. ..	..	1 " 4
" Nut..	40	1	62	60	.. .. ..	..	1 " 4
Annesley .. ..	30 to 35	1	250	250	700 tons in 8½ hours ..	115	1 " 4
Clifton .. ..	15	2	60	10	{ 350 to 400 tons per day } of 10 hours .. ..	All fixed	1 " 1.8

II. *Wet Cleaning.*

Name.	Type of Machine.	Nominal Capacity per Day of 10 Hours.	Actual Capacity per Day of 10 Hours.	Dirt in Coal.	Taken out.	Left in.	Smudge Tanks. Capacity.	Settling Ponds. Capacity.	Tank Capacity per Ton washed per Hour.	Smudge.* Settling.*
Barrow ..	Robinson	tons 300	tons 240 to 250	per cent. ..	per cent. 8 to 10	per cent. 4	cu. ft. 6,500	cu. ft. 21,640	cu. ft. 2.17	cu. ft. 7.76
Aldwarke..	Trough ..	..	180	..	12	4	20,115	Nil	11.27	Nil
Nuntery ..	" ..	..	220	..	10	..	5,000	16,000	..	..
Clifton ..	Coppée ..	400	300	..	15 to 18	..	12,150	..	3.04	..

\* These are calculated on maximum capacity of the apparatus for want of more reliable data.

Table 125—continued.—III. Trough Washing.

Name.	Dimension of Double Trough Washer.	Washing Capacity.	Inclination of Troughs.	Dirt Removed.	Dirt Left in.	Remarks.
Aldwarke Main ..	{ 50 yd. 16 by 9 }	150 tons in 12 hours..	{ 1½ in. per yd.; washer } { same inclination .. }	per cent. 12	per cent. 4	Crushed.
Nunnery .. ..	{ 36 yd. 16 by 9 }	220 tons in 10 hours..	{ From coal hopper to } { troughs 2 in. per yd.; } { washer level .. .. }	10	..	{ Smudge and peas not } { crushed. }

Name.	Box.		Weight.	Capacity.	Diameter of Wheels.		Wheels.	Doors.	Ends.
	Length.	Breadth.			in.	in.			
Barrow .. ..	ft. in. 4 0	ft. in. 3 0	..	cwt. 9 to 10	8	24	Flange	None	Fast
Aldwarke .. ..	3 6	2 10	3½	8 to 9	8	..	"	"	"
Nunnery .. ..	4 0	3 0	..	9 to 10	10½	23	"	"	Open
Anneley .. ..	4 0	3 0	..	11	..	26	"	"	Fast
Clifton .. ..	3 6	3 0	..	7	8	22	"	"	

NOTE.—All are made of wood.

Table 125—*continued*.V. *Costs (Labour and Repairs only) per ton of Coal.*

Name.	Dry Cleaning.	Wet Cleaning.	Type of Washer.	Condition of Coal previous to Washing.
	<i>d.</i>	<i>d.</i>		
Barrow .. ..	1½	2½	Robinson	Crushed.
Aldwarke Main ..	..	2½	Trough	..
Nunnery .. ..	3	1·40	"	Not crushed.
Annesley .. ..	2½ to 3	No cleaning here.	..	..
Clifton .. ..	3 to 4	6 to 7	Coppée	Not crushed.*

\* Machine not in complete effective working.

COAL CLEANING: *Generalities*. (Min. Inst. Scotland.)

The methods and appliances in use in any one district can seldom be adopted as a whole in a similar form in another. This applies in many instances to collieries in the same district, and even to different seams worked by the same shaft. The nature of the coal, the associated and interbedded strata, the skill, customs, and prejudices of workmen, the markets to be supplied, the varying requirements of competition, and the caprice of the public, have all to be taken into account when designing plant for classifying and cleaning coal.

While coal with marked characteristics can with care be selected underground so as to be filled separately, no process can be profitably applied underground for effectually removing refuse, especially the smaller particles. To clean coal properly, it must be treated on the surface.

As a considerable percentage of dross is made in transit from the cage to the railway wagon, it is evident that the best results are got where attention is paid to the form of hutch and tumbler, the inclination of screens, and the drop into wagons; and this is specially important in the case of soft coals. A number of contrivances to lessen breakage are mentioned in the report. The careful hand-packing of large coal into the wagons, as practised in the Nottingham district, has advantages.

For effective screening, especially when a large output has to be dealt with, there appears to be no better contrivance than the single or double jigger, or shaking screen, going at 90–100 strokes per minute, and having an inclination suited to the class of coal to be dealt with. There is a preference for wire-meshing for such screens at some collieries, and at others bars or perforated plates are preferred.

For picking, the shaking screen just referred to, or the travelling band, or both combined, is the most effective and economical—the

*Generalities—continued.*

band being about 4 ft. wide, 40–60 ft. long, and moving at a speed of 30–60 ft. per minute, according to the quantity of coal to be passed. Ample length of band allows large coal to be sized and loaded into separate wagons by hand with despatch and economy.

In every case it is necessary that the coal be delivered regularly from the tip hopper to the jigger or travelling band. This can be accomplished by regulating sluices worked by an attendant or automatically by the intervention of a slow-motion band.

Good light is essential to efficient picking.

A rough rule for deciding the number and length of picking tables may be stated as follows:—One picking table for every 30 tons per hour of tripping output, travelling at the rate of 40 ft. per minute, and having a length of 10 ft. for every 3 per cent. of material to be picked off, plus 15 ft.

The cost for labour of this system may be taken at about  $1\frac{1}{2}d.$ – $2d.$  per ton of round coal for every 5 per cent. of material picked out of that coal.

For round coal, say above  $1\frac{1}{2}$  in. cube, the dry process is universally employed, and this process can be successfully applied to nuts from say  $\frac{3}{4}$  in. upwards, where the refuse does not exceed 2–3, or even 4 per cent.; and the table capacity required, judging from the examples in the report, is about one table for every 20 tons per hour, travelling at the rate of 30 ft. per minute, and having an effective length of 15 ft. for every  $1\frac{1}{2}$  per cent. of material picked off. The cost for labour will probably be  $\frac{3}{4}d.$ – $1\frac{1}{2}d.$  for every 1 per cent. picked off. Balanced screens, on which the coal is picked, are available only when the amount of material to be picked off is very small, say 1– $1\frac{1}{2}$  per cent. For all small under  $\frac{3}{4}$  in., and for dress from  $1\frac{1}{2}$  in. downwards, with more refuse than 2–4 per cent., the wet process is most applicable.

In the wet process it is desirable to have the arrangement so that the small coal can be delivered direct from the screens into the washing tanks without the intervention of wagons. In all the systems of washing, the best results are obtained by sizing the small coal before it reaches the machine. This can most conveniently be done by passing it through revolving screens with meshes of varying size. The supply and degree of pulsation or agitation of the water require careful adjustment to suit the various sizes of coal to be treated, and the relative specific gravity of coal and impurities.

To remove the refuse from the smaller sizes, say under  $\frac{3}{4}$  in., the felspar washer is the most effective. The felspar system is the most valuable where the coal is crushed before washing and is to be used for coke making.

Where the coal and the refuse approach one another in specific gravity, it appears that in some cases the trough washer gives the best results. It is applicable for small quantities only, and requires a large flow of water and extra labour, but it has the recommenda-

*Generalities—continued.*

tion of simplicity and small capital cost. It may also be sometimes utilised as a means of transport where the distance from the pit to the wagons or coke ovens is considerable.

The Robinson washer is cheap as regards first cost and upkeep, and requires little water. It largely depends for its efficiency on the attention and skill of the man in charge, who may often be tempted to pass more through it than it can effectually clean.

Speaking generally, more elaborate machinery is effective in avoiding waste in proportion to its cost; but the capital charges and upkeep are also high in proportion.

Other things being equal, coal will be washed best with an abundant supply of clean water; but the more water used, the greater the risk of fine coal being lost, and the greater the difficulty of filtration. Water to wash coal for coking should not be often used over again, as dirty water dulls the coke.

The particulars furnished as to settling ponds do not give sufficient data to justify any definite conclusion as to their capacity in relation to the quantity of coal washed. In most cases no record was kept of the quantity of water used; but settling ponds are a necessity, and their capacity will depend on the special circumstances of each case.

There seems no better way of filtering the foul water, after it has passed through the settling ponds, than pumping it on to the rubbish heap, and allowing it to percolate through, as at Earnock.

The washed gum of coal not suited for coking is meantime used almost entirely for firing colliery boilers. Briquettes are made of it to a small extent, but new outlets are required for this product.

The large quantity to be treated daily, and the varying nature and proportions of the coal and dirt to be separated, render washing, at most collieries, a troublesome process; and unqualified satisfaction is seldom expressed as regards any machine in use. In some cases the machine may not be quite adapted to the peculiarities of the coal treated, or it may be over-driven, or not have a sufficiency of water, or be allowed to get out of repair, all or any of these causes leading to disappointment as to results.

A separate siding for each class of coal is a desirable arrangement.

## MINE SURVEYING.

## MEASURING INACCESSIBLE DISTANCES.

1. In measuring along the line  $ab$ , Fig. 12, a river intervenes, so that the distance  $cb$  is inaccessible to direct measurement with a chain. From the point  $c$  set off a line  $cd$  at right angles to the line  $ab$ , and erect a staff at the point  $d$ . Then set off a line  $de$  at right angles to the imaginary line  $db$ , till it cuts the line  $ac$ . Measure the line  $ce$ . Then as  $ce$  is to  $cd$ , so is  $cd$  to  $bc$ . Say  $ce = 60$  ft., and  $cd = 90$  ft.; then  $60 : 90 :: 90 : 135$ ; thus  $bc = 135$  ft.

2. To apply the theodolite to the foregoing example, plant the theodolite at  $a$ , Fig. 13, and at any convenient distance raise a perpendicular  $ab$ ; then remove the theodolite to  $b$ , and make the angle  $abc =$  the angle  $abd$ . The distance between  $ac$  will = the distance between  $ad$ .

3. Or, set up the theodolite at  $a$ , Fig. 14, and measure any angle, say  $90^\circ$ ; walk along the line  $ab$  till the theodolite reads half the angle ( $45^\circ$ ); measure the distance  $ab$ , which will = the distance  $ac$ .

4. Or, plant the theodolite at  $c$ , Fig. 15, and prolong the line  $ac$  to  $d$ , and the line  $bc$  to  $e$ ; measure the lines  $ac$  and  $bc$ , making  $ac = cd$  and  $bc = ce$ . The distance  $de$  will then = the distance  $ab$ .

5. On the line  $ab$ , Fig. 16, an inclosed plantation intervenes. Then at points  $c$  on line  $ab$  plant staves, and from each point set off at right angles to the line  $ab$  lines  $d$ , and at right angles to these lines  $d$  set off a new line  $hi$ , which will pass the obstacle, repeating these operations with lines  $fg$  in order to regain the original line  $ab$ .

6. On the line  $ab$ , Fig. 17, a building interrupts the surveyor. To overcome this by means of a chain and angular instrument, the first step is to measure an angle which will clear the obstacle, viz.  $acd$ , at say  $140^\circ$ . At the point  $d$  the theodolite is then planted, and a second angle  $deb$  is measured off = the supplement of the first, or  $70^\circ$ . Measure along the line  $de$  till a point is reached exactly = the length of the line  $cd$ . Place the transit at  $e$ , and with the telescope pointing on  $d$ , get the angle exactly  $140^\circ$  or = the angle  $acd$ . Then the true continuation of the line  $ab$  is found by bringing a staff into the line marked by the cross-hairs of the telescope.

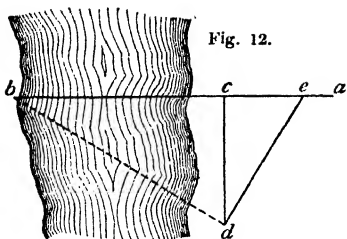


Fig. 12.

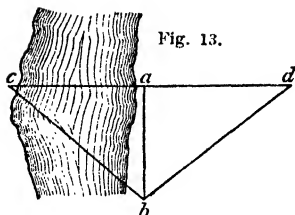


Fig. 13.

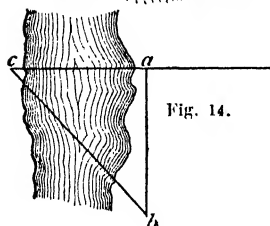


Fig. 14.

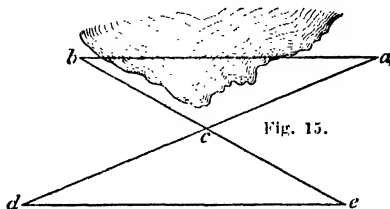


Fig. 15.

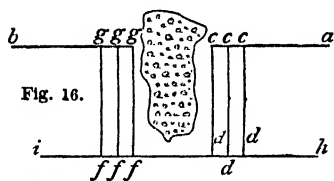


Fig. 16.

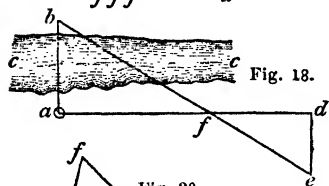


Fig. 18.

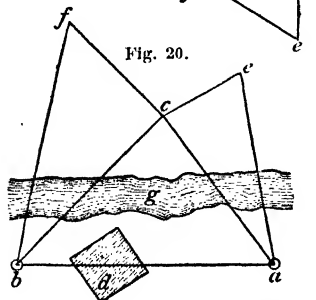


Fig. 20.

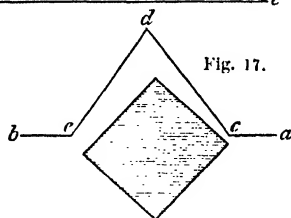


Fig. 17.

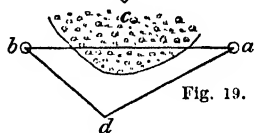


Fig. 19.

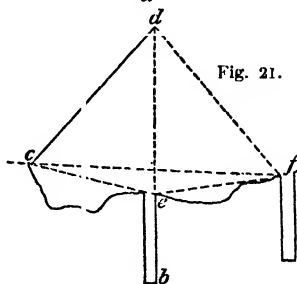


Fig. 21.

Inaccessible Distances.

MEASURING SHAFTS, LEVELS, AND INCLINES.

*Shafts.—To find Distances between.*

1. To find the distance between two shafts  $ab$ , Fig. 18, separated by a stream  $c$ , plant a staff at  $b$  in line with  $a$ , and set off a line  $ad$  at right angles to the line  $ab$ , fixing a staff at  $d$ . Then at right angles to the line  $ad$  draw a line  $de$ , fixing a staff at  $e$ . Next, from the point  $a$ , measure off a certain distance on the line  $ad$ , and fix a staff at the spot, say  $f$ ; adjust the staff on the line  $de$ , so that it exactly covers the staff  $b$ . Measure the intervals between  $a$  and  $f$ ,  $f$  and  $d$ ,  $d$  and  $e$ ; then as the angle  $afb =$  the angle  $dfe$ , and  $a$  and  $d$  are each right angles, therefore as  $fd$  is to  $de$ , so is  $af$  to  $ab$ ;

or,  $fd$  (say 100 ft.):  $de$  (70 ft.):  $af$  (200 ft.):  $ab$  (140 ft.).

2. To find the distance between two shafts  $ab$ , Fig. 19, when a plantation  $c$  intervenes, set up the theodolite at  $d$ , and take the angle  $bda$ , say  $= 90^\circ 30'$ ; measure the distances between  $d$  and  $b$  and  $d$  and  $a$ , say respectively 48 and 62 chains. Then draw the line  $db$ , and at  $d$  mark off the angle with the protractor  $= 90^\circ 30'$ . By applying the scale to  $db$  mark off 48 chains, and by the same process to  $da$  62 chains; then, on joining the points  $ab$  and applying the same scale, the distance will be arrived at.

3. To find the distance between two shafts  $ab$ , Fig. 20, which are simultaneously visible only from one spot  $c$  on the opposite side of a stream, and are separated by a building  $d$ , plant the theodolite at  $c$ , and fix poles at known intervals at  $e$  and  $f$ . Measure the angles  $acb$ ,  $ace$ , and  $acc$ . The distance between  $c$  and  $e$  being known, the length of the line  $ac$  can be ascertained by the rule "given one side and two angles of an oblique-angled triangle, to construct it and measure the other parts." Next measure the angles  $bce$  and  $cfb$ , and thus find the length of the line  $cb$ . Then having found the lengths of the lines  $ac$ ,  $bc$ , and the angle  $acb$ , the length of  $ab$  may be deduced as in *Ex. 2*.

4. To find the distance between two shafts, and of each shaft from two distant stations, the distance between the stations and the horizontal angles with the two shafts from the stations being known. Thus in the case of the two shafts  $ab$ , Fig. 21, given the horizontal angles by transit theodolite to be:— $ecd = 106^\circ 48' 20''$ ,  $fed = 90^\circ 35' 15''$ ,  $cde = 23^\circ 40' 15''$ ,  $cdf = 57^\circ 17' 30''$ , and the line  $cd = 890$  links; then make a horizontal line  $cd$  exactly 890 links long; with the protractor set off from  $cd$  with its centre at  $c$ , the angle  $ecd$  at  $106^\circ 48' 20''$ , and from the same centre the angle  $fed$  at  $90^\circ 35' 15''$ . Then draw the lines  $ce$  and  $cf$  to any convenient length. Next, setting the protractor to the line  $cd$  with its centre at  $d$ , set off the angle  $cde$  at  $23^\circ 40' 15''$ , and  $cdf$  at  $57^\circ 17' 30''$ , and remove the instrument. Then, having drawn the lines  $de$  and  $df$ , the point of intersection of  $de$  with  $ce$  will give the position of the first shaft; the intersection of  $df$  with  $cf$  will give the position of the second shaft; application of the scale to



*Shafts—continued.*

the line  $ef$  will give the distance from shaft  $a$  to shaft  $b$ ; and lines  $de$  and  $df$  measured on the same scale will give the distances of the stations  $cd$  from each shaft.

*Shafts.—To find Depths for.*

1. To find the depth at which the shaft  $ab$  Fig. 22 will strike the vein  $c$ , when the underlie of the vein and the distance between the outcropping  $d$  and the top  $a$  of shaft are known, assume the angle  $bda = 44^\circ 40'$  and the distance  $a$  to  $d = 90$  links; draw a horizontal line  $ad$ , set off the line  $db$  at  $44^\circ 40'$ , and measure 90 links on  $ad$ ; a perpendicular line falling from  $a$  will strike the vein  $c$  at  $b$ , and the length from  $a$  to  $b$  will be the depth of the shaft in links.

2. Or, multiply the natural tangent of the angle  $bda$  by the distance  $a$  to  $d$ , thus—

$$\begin{array}{rcl} \text{Natural tangent of angle } bda \ 44^\circ 40' & = & \cdot 988432 \\ \text{Distance } a \text{ to } d & = & 90 \end{array}$$

$$\text{Depth of shaft in links} = \underline{\underline{88\cdot958880}}$$

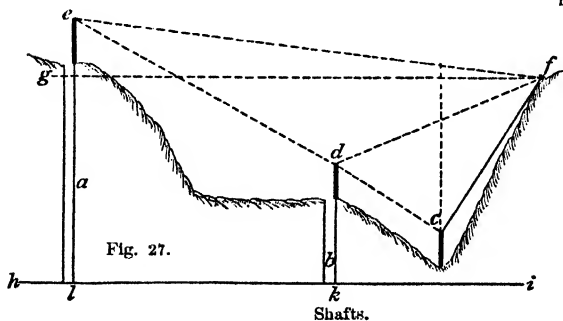
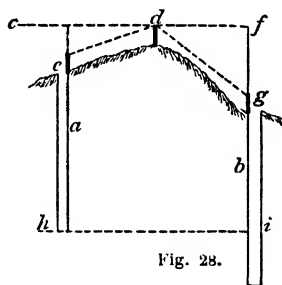
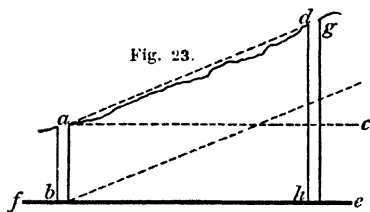
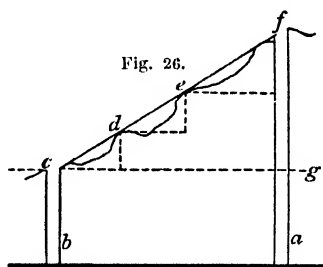
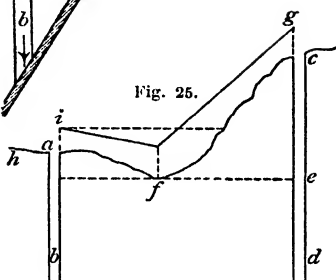
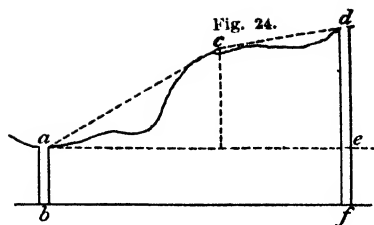
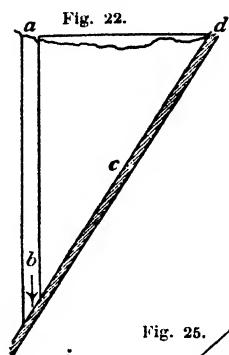
3. To find the depth required in a second shaft to reach the same bottom level as the first shaft, when the depth of the first shaft and angle of elevation and hypotenuse of the second shaft are known. In Fig. 23, the depth of the first shaft  $ab = 87$  yd., the angle of elevation  $cad = 32^\circ 25' 30''$ , and the hypotenuse  $ad = 220$  yd. Then draw the horizontal line  $ef$ , and from it measure up 87 yd. from  $b$  to  $a$ ; with the protractor applied to the line  $cf$ , centre at  $f$ , set off the angle  $cbc$  at  $32^\circ 25' 30''$ ; with a parallel rule draw the line  $ad$  parallel to  $bc$ , so that the angle  $cad$  will = the angle  $cbc$ . Then a perpendicular line dropped from a point  $d$  on the line  $ad$  at 220 yd. from  $a$ , will give the depth in yd. which the new shaft  $gh$  sunk at  $d$  must have in order to reach the same level as the bottom of shaft  $ab$ .

4. Or, multiply the sine of the angle of elevation by the hypotenuse for the perpendicular, and the cosine of the angle of elevation for the base. Thus in Fig. 24, the shaft  $ab$  is 80 yd. deep, the angles of elevation (in this instance being two, owing to the inequality of the surface) are  $39^\circ 31'$  at  $a$ , and  $15^\circ 11'$  at  $c$ , while the hypotenuse  $ae = 240$  yd., and  $cd = 160$  yd. Then—

$$\begin{array}{rcl} \text{Angle } a \ 39^\circ 31' & = \text{sine } \cdot 636303 \times 240 & = 152\cdot712720 \\ \text{Angle } c \ 15^\circ 11' & = \text{sine } \cdot 261909 \times 160 & = 41\cdot905440 \end{array}$$

$$\begin{array}{rcl} \text{Total difference of level } de & = & 194\cdot61816 \\ \text{Add depth of shaft } ab & = & 80 \end{array}$$

$$\text{Total depth of shaft } df = 274\cdot61816$$



*Shafts—continued.**Shafts.—To find differences of Level of.*

1. At top. The angles of elevation between the two shafts  $a b$  and  $c d$ , Fig. 25, and the hypotenuse being known, their difference of level at the mouth is found in the following way. Suppose the angle of elevation  $e f g = 44^\circ 20'$ , and the angle  $h f i = 10^\circ 35'$ , while the hypotenuse  $g f = 870$  yd., and the hypotenuse  $i f = 630$  yd. Then draw the horizontal line  $h c$ , set off the above angles from  $f$ , and mark the distances named on  $g f$  and  $i f$ . The difference of level between the intersection of the telescope of the theodolite at  $i$ , and a staff of similar height at  $g$  will give the difference of elevation between the mouths of  $a b$  and  $c d$ ; or it may be seen from the scale.

2. Or, supposing the angles of elevation in Fig. 26, between shafts  $a$  and  $b$  on the line  $c g$ , to be from  $c = 42^\circ 10'$ , from  $d = 41^\circ 40'$ , from  $e = 43^\circ 25'$ , and hypotenuse  $c d = 80$  yd.,  $d e = 85$  yd.,  $e f = 120$  yd., then multiply the sines of the angles by the hypotenuses, thus—

Angle from $c$	$42^\circ 10' = \text{sine } \cdot 671290 \times 80 =$	$53 \cdot 7032$
"	$d \ 41^\circ 40' = \text{sine } \cdot 664796 \times 85 =$	$56 \cdot 50766$
"	$e \ 43^\circ 25' = \text{sine } \cdot 687299 \times 120 =$	$82 \cdot 47588$
Total difference of level in yd. =		<u><math>192 \cdot 68674</math></u>

3. Or, when the angles of elevation or depression from two distant stations are known. Suppose two shafts  $a b$ , Fig. 27, and that the angle from station  $c$  to point  $d = 45^\circ 10'$ , that from  $c$  to  $e = 44^\circ$ , and that from  $c$  to  $f = 60^\circ$ , and the line  $c f = 1000$  links. Take at  $f$  the angle of depression  $f$  to  $d$ , or  $g f d = 30^\circ 15' 22''$ , and the angle of elevation  $f$  to  $e$ , or  $g f e = 15^\circ 9' 11''$ . Draw the horizontal line  $h i$ , and from point  $c$  set off angle  $h c d = 45^\circ 10'$ , angle  $h c e = 44^\circ$ , and angle  $i c f = 60^\circ$ . From point  $c$  draw the lines  $c d$ ,  $c e$ ,  $c f$ , making the length of  $c f = 1000$  links, and  $f g$  parallel to  $h i$ . At point  $f$ , set off the angles  $g f d = 30^\circ 15' 22''$ , and  $g f e = 15^\circ 9' 11''$ , and draw the lines  $f d$ ,  $f e$ . Then the point where  $f d$  intersects  $c d$  will be the top of shaft  $b$ , and the point where  $f e$  intersects  $c e$  will be the top of shaft  $a$ . Applying the same scale as before to the lines  $d k$  and  $c l$ , their difference will = the difference in elevation of the mouths of the two shafts.

4. At bottom. Suppose the depth of shaft  $a$ , Fig. 28, = 60 yd., and of shaft  $b = 55$  yd., while the angle of depression  $f d g = 43^\circ 10' 15''$ , angle  $c d e = 21^\circ 2' 10''$ , the distance  $g d = 500$  yd., and the distance  $c d = 400$  yd. Then draw the horizontal line  $c d f$ , and with the protractor set off from  $d$  the angle  $f d g$  at  $43^\circ 10' 15''$ , and the angle  $c d e$  at  $21^\circ 2' 10''$ , and draw the line  $g d = 500$  yd., and the line  $e d = 400$  yd. The points  $e g$  are thus the tops of the shafts  $a b$ , and perpendicular lines

*Shafts—continued.*

dropped from the horizontal line  $c d f$  to the points  $e g$  will give, when measured on the scale, the differences in elevation at the mouths of the shafts. Then prolong these perpendicular lines and measure on  $a$  60 yd., and on  $b$  55 yd. in depth, and draw the horizontal line  $h i$  from the bottom of shaft  $a$ , so that it intersects shaft  $b$ . The difference between the horizontal line  $h i$  and the bottom of shaft  $i$  on the scale is the measure sought.

*Levels.—To find Length required.*

1. When the depth of the shaft, its distance from the vein, and the dip of the vein are known.

Suppose the shaft  $a$ , Fig. 29, is 50 yd. deep and 100 links distant from the outcrop  $b$  of the vein  $c$  which dips at  $40^\circ$ . Connect the outcrop  $b$  with the top of shaft  $a$  by drawing the line  $d = 100$  links, and from the line  $b d$  at  $b$ , set off the angle  $g b d = 40^\circ$ . A perpendicular line from  $d$ , 50 yd. deep, will represent the shaft. From the bottom of the shaft draw the horizontal line  $e f$  parallel to  $d b$  and measure it by the scale; the number at the point of intersection between  $e f$  and  $b g =$  length of level in links.

2. Or suppose the depth  $c d$  of the shaft  $a$ , Fig. 30, = 50 yd., and the angle  $c d e = 44^\circ 10'$ , being the dip of the vein  $b$ , then the

$$\begin{array}{rcl} \text{Natural tangent of } c d e 44^\circ 10' & = & \cdot 971326 \\ \text{Multiplied by the depth } c d & = & \underline{50} \\ \text{Length of level } c f \text{ in yd.} & = & 48 \cdot 566300 \end{array}$$

3. Or, suppose the depth of shaft  $a$ , Fig. 31, = 50 yd., the distance  $d e$  between the shaft  $a$  and outcrop of vein  $b = 120$  yd., and the angle  $d e f$  or dip of vein =  $40^\circ$ , then the

$$\begin{array}{rcl} \text{Natural tangent of angle } d e f 40^\circ & = & \cdot 839100 \\ \text{Multiplied by distance } d e & = & \underline{120} \\ \text{Distance } d f & = & 100 \cdot 692000 \\ \text{Less distance } d g & = & \underline{50} \\ \text{Then distance } g f, \text{ in yd.} & = & 50 \cdot 692000 \end{array}$$

The angle at  $f = 90^\circ -$  angle at  $e$  (which is, say  $47^\circ 10'$ ), or  $f = 42^\circ 50'$ , then the

$$\begin{array}{rcl} \text{Natural tangent of } e 42^\circ 50' & = & \cdot 927091 \\ \text{Multiplied by distance } g f & = & \underline{50 \cdot 5} \\ \text{Length of level } c, \text{ in yd.} & = & 46 \cdot 8280955 \end{array}$$

*Levels.—To find Depth at which known Length shall strike the Vein.*

1. Suppose the depth of shaft *a*, Fig. 29, = 50 yd., the distance from shaft *a* to outcrop *b* of vein *c* = 100 links, the dip of vein *c* =  $40^\circ$ , and the length of level *ef* = 20 yd. Draw the horizontal line *db* 100 links long, and at *b* set off the angle  $40^\circ$ ; drop a perpendicular line *de*, and apply a parallel ruler to the line *db*, running it down till the level *ef* exactly fills the space between *de* and *bg*. This spot will indicate where the level will touch the shaft *de*, and the depth may be ascertained by applying the scale to the shaft *de*.

2. When the shaft is continued below the vein and a returned heading is made. Suppose the shaft *a*, Fig. 32, to be distant 120 yd. from the outcrop *e* of the vein *b*, the angle of dip of vein *b* to be  $47^\circ 12'$ , and that the shaft *a* is continued in depth for 80 yd. below the point where it intersects the vein *b*. Draw a horizontal line *de*, and from the point *e* set off with the protractor the angle  $47^\circ 12'$ ; then a perpendicular line *df* falling from *d* will intersect the vein *eg* at *h* (and by measuring on the scale will give the depth of shaft *df* to that point), and extended 80 yd. deeper to *f* will indicate where the level is to be run; apply the parallel ruler to *de*, run it down to point *f*, and apply the scale to line *gf*.

*Levels.—To find Depth of Shaft at Intersection of Vein, and Lengths of Levels, when one level is above and one below the intersection.*

Let the distance *de*, Fig. 32, = 120 yd., the angle of dip =  $47^\circ 12'$ , the depth of shaft *a* from *d* to first level *ik* = 30 yd., and the depth from *h* to *f* = 80 yd.; then the

Natural tangent of angle at <i>e</i> $47^\circ 12'$	=	1.079902
Multiplied by distance <i>de</i>	=	120
		<hr/> 21598040
		1079902

Depth at intersection, in yd.	=	129.588240
Less depth <i>di</i>	=	30

Depth <i>ih</i> , in yd.	=	<hr/> 99.588240
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The angle at *h* =  $90^\circ - 47^\circ 12' = 42^\circ 48'$ ; then the

Natural tangent of angle at <i>h</i> $42^\circ 48'$	=	.926010
Multiplied by distance <i>ih</i>	=	99.5

Length of level <i>ik</i> , in yd.	=	<hr/> 92.1379950
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Also the

Natural tangent of angle at <i>h</i> $42^\circ 48'$	=	.926010
Multiplied by distance <i>hf</i>	=	80

Length of level <i>gf</i> , in yd.	=	<hr/> 74.080800
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*Levels.—To find Direction and Length when required to strike a fixed point at right angles.*

Thus, in Fig. 33, it is required from the bottom of incline *a* to drive a level *b* so as to cut the shaft *c* at right angles. Suppose incline *a* to be 60 yd. long and shaft *c* to be 30 yd. deep, then divide the side *c* opposite the required angle of *b* by the hypotenuse, and the quotient will be the sine of the angle. Thus,

$$\begin{array}{r} 60 \text{ ) } 300 \text{ ( } \cdot 5 = \text{ sine } 30^\circ \\ \underline{300} \end{array}$$

The angle at *d* =  $90^\circ - 30^\circ = 60^\circ$ . Then the

$$\begin{array}{r} \text{Natural cosine of angle at } e \text{ } 30^\circ = \cdot 866025 \\ \text{Multiplied by } a \quad \quad \quad = \underline{\quad 60 \quad} \\ \text{Length of level } b, \text{ in yd.} = \underline{\underline{51\cdot961500}} \end{array}$$

Or, the

$$\begin{array}{r} \text{Natural tangent } d \text{ } 60^\circ \quad \quad \quad = 1\cdot732051 \\ \text{Multiplied by } c \quad \quad \quad = \underline{\quad 30 \quad} \\ \text{Length of level } b, \text{ in yd.} = \underline{\underline{51\cdot961530}} \end{array}$$

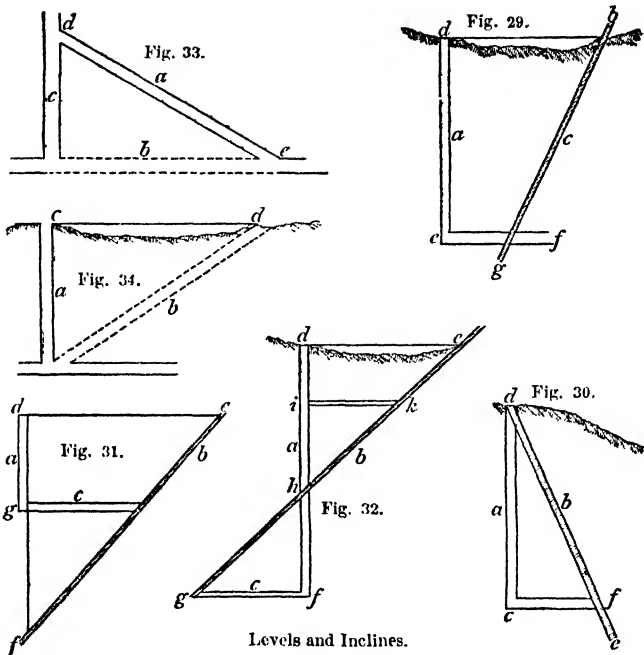
*Inclines.—To find Direction and Length.*

In Fig. 34, suppose the depth of shaft *a* = 80 yd., the distance *cd* = 60 yd., then find the length and angle of incline *b* so as to strike the surface at *d*. Divide the side *a* opposite the required angle by the other side *cd*; the quotient will be the natural tangent of the angle. Thus:—

$$\begin{array}{r} 80 \text{ ) } 6000 \text{ ( } \cdot 75 = \text{ tangent } 36^\circ 52' \\ \underline{560} \end{array}$$

The angle at *d* =  $90^\circ - 36'' 52' = 53^\circ 8'$ . Then the

$$\begin{array}{r} \text{Natural secant of } 53^\circ 8' \quad \quad \quad = 1\cdot666792 \\ \text{Multiplied by } cd \quad \quad \quad = \underline{\quad 60 \quad} \\ \text{Length of incline } b, \text{ in yd.} = \underline{\underline{100\cdot007520}} \end{array}$$



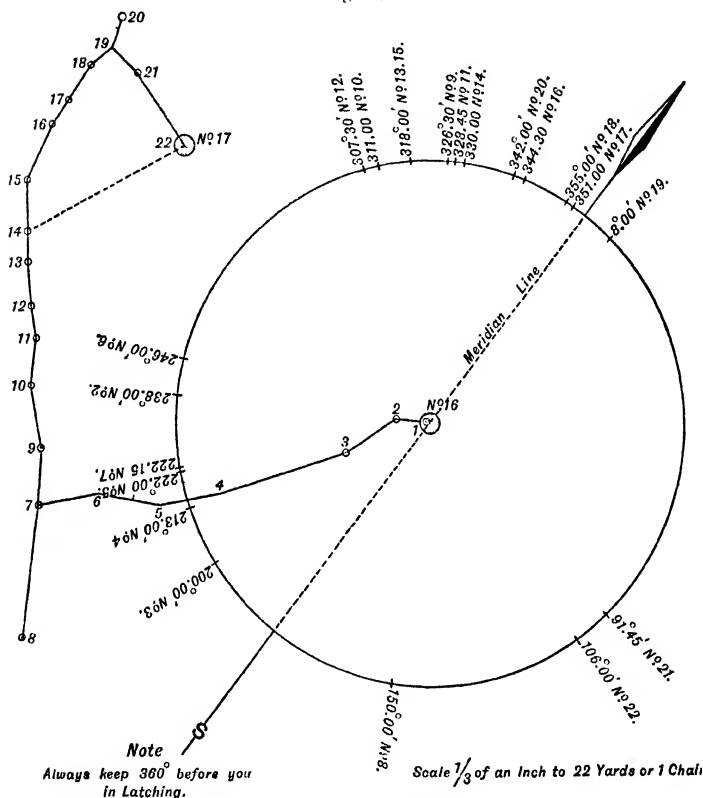
### *Latching or Dialling. (Merrett.)*

“Latching” or “dialling” is a term used by miners when an underground survey is required of the course that has been excavated from one shaft of the mine to another. This survey is then transferred to the estate plan, by the guidance of the position of the shafts, which are accurately shown on both surveys. By reference to Fig. 35, which is an actual survey, it will be seen that the lengths are taken by the chain or tape in links, and the angles are taken by the needle or magnetic meridian with a circumference, called by miners a “dial.” The legs of this instrument are made with a screw joint in the middle. It has an extra set of points to screw on when the mine workings are low roofed. The survey commences at shaft No. 16, and is carried to shaft No. 17. The chain lines and angles are all plotted from that point. The circle shows the protractor with the meridian line through the centre, and all the angles marked thereon for

*Latching*—continued.

plotting. The “field-book” as it were, is on the margin, containing only the numbers, lengths, and angles. Great accuracy must be observed in taking the angles and lengths.

Fig. 35.



Latching or Dialling.



*Surveying Instruments.*

When minerals of value are found in a new country a survey is generally made, and plans drawn up upon which angles are secured for the future working. The instruments used for such surveys were generally of a class adapted to be used above or under ground. Mr. Stanley in his excellent practical work on surveying

instruments\* defines the qualities that a mining-survey instrument should possess, as follow:—

1. That there shall be means provided for shortening the tripod to work in strata of small depth.
2. That the instrument shall be low and compact in itself, that the head of the surveyor may be placed above it, if possible, even in shallow workings.
3. That great extent of adjustment of the compass-box to horizontality shall be given in the construction of the instrument, on account of the difficulty frequently of extending the tripod legs in close workings and from inclination of floor.
4. That it is desirable that the telescope, if there is one to the instrument, shall, besides taking nearly horizontal angles, take also a vertical position, to be able to sight lines

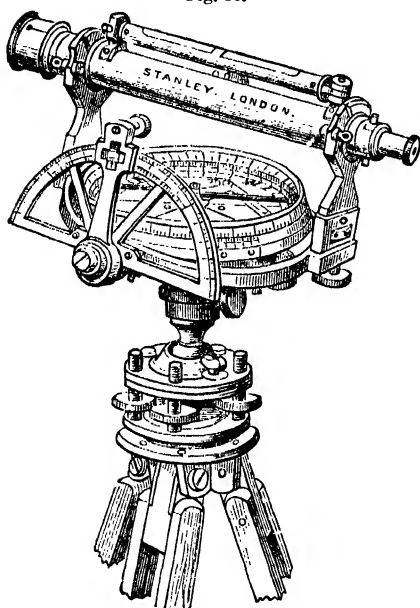


Fig. 36.

Improved Miners' Dial.

from top to bottom of a shaft, or *vice versa*. The illustration is of one of the best form of mining dials, for which we give Mr. Stanley's description.

*Improved Miners' Dial.*—The illustration, Fig. 36, is the form of dial now generally approved. The telescope when this is used is supported in Y's; but the whole of the Y arrangement can be detached by loosening the two milled heads placed under the Y's, and the telescopic arrangement be replaced by extended open

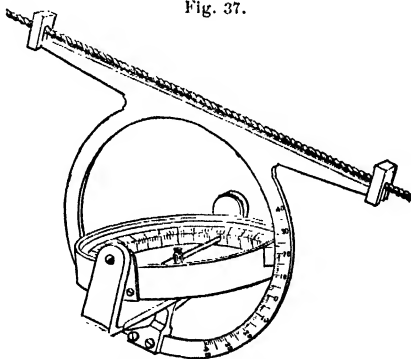
*Instruments—continued.*

sights. These are not shown in the engraving. The horizontal circle, instead of being placed in the interior of the box, is placed on the exterior rim, and reads with two verniers—not for correction, but for convenience of reading in different positions. The compass is divided upon the upper surface of the step to degrees, and in the same manner on the interior cylindrical surface of the step. This last often permits the compass to be read in a close working when the upper surface could not either be lighted or sighted. The plane of the compass is divided to  $10^{\circ}$  as usual. The compass adjusts by clamp and tangent motion. The axis of the instrument is supported upon a ball and socket arrangement for roughly bringing the compass to level, and a parallel plate adjustment for final setting. The ball is fixed by clamping a pair of plates together by thumb-screws. Each plate is hollowed in the centre to hold nearly half the ball. When fixed, the instrument is found to be very rigid. The tripods, not shown, have sliding fittings, which will clamp to any height from 2 feet 6 inches to 4 feet, which is a much better and more portable arrangement than the old form of loose pieces screwed together.

For close much-inclined mineral veins the hanging compass is found to be of the greatest utility. The illustration, Fig. 37, is Mr. Stanley's modification of this instrument. The compass is suspended from a copper wire or cord in any position where the two ends of the cord may be fixed or held. Where

the inclination is great, a knot is made or a clamp fixed on the cord to prevent the instrument slipping down. The compass is balanced on centres, so that it takes its own level position by gravitation, and being suspended in a divided ring, inclination may be read off at the same time as taking the bearings of the line. When the cord is in the centre of the line this is taken correctly, but it will more frequently happen that observation can only be made near the ends of the line. When this is the case the mean of observations at each end of the line may be taken, or if one end observation only can be taken a small allowance may be made for the sag of the line. The instrument is made in two sizes, 5 inches and 3 inches, the last being a very light instrument to carry.

Fig. 37.



Stanley's Hanging Dial.

BOOK

Table 126.—Order of Superposition of British Rocks, showing the Systems, Formations, Groups of Strata, Characteristic Rocks, Prevalent Minerals, Typical Fossils. (Readwin).

SYSTEMS.	GEOLOGY.			MINERALOGY.	PALÆONTOLOGY.
	FORMATIONS.	GROUPS OF STRATA.	CHARACTERISTIC ROCKS.	PREVALENT MINERALS.	TYPICAL FOSSILS.
POST-TERTIARY.	RECENT.	The deposits of rivers, lakes, and seas . . . . . 1	Soils, silt, sand, gravel, shingle, brick-earth, alluvium	Cal-tuff, Rag-Iron Ore, Amber, Gold, Platinum	Fossils of existing species, Human remains
CENOZOIC.	PLEISTOCENE.	Drift and Glacial beds . . . . . 2	Gravel, sands, brick-earth, old cave deposits	Flint . . . . . 2	Shells of living species, Ox, &c. [ <i>Flint implements</i> ]
		Mammaliferous, or Norwich crag . . . . . 3	Beds of shelly clay, sand, loam, layers of shingle, &c.	Disseminated Iron Oxide, Phosphatic Nodules	Mastodon, Mollusca
	PLIOCENE.	Red crag of Norfolk and Suffolk . . . . . 4	Ferruginous shelly sand and loam	Iron Oxide, Amber, Argonite . . . . . 5	Bones and Teeth of Mammalia, Marine Shells
		Coralline crag of Suffolk . . . . . 6	Whitish shelly sand, flaggy shell beds	Lignite, Iron Ore . . . . . 6	Sponges, Polyzoa, Echinodermata, Shells
	MIOCENE.	Leaf-beds of Mull, and ash-beds of Antrim . . . . . 6	Leaf and ash beds, basalt	Lignite, Ironstone, Pyrites, Amber . . . . . 7	Plant remains
		Hempstead beds, Bovey Tracy clays, &c. . . . . 7	Marine and freshwater sands and clays	Gypsum, Calcite, Iron Oxide	Fluvio-Marine Shells and Plant remains
	EOCENE.	Bembridge beds . . . . . 8	Marine and freshwater limestone, marl, and clay	Lignite, Clay-Ironstone . . . . . 9	Land Shells, Turtles, Paleotherium
		Osborne, St. Helen's, and Headon beds . . . . . 9	Marine and freshwater beds, alternating		Marine Mollusca
	MIDDLE.	Bagshot beds, Bracklesham beds . . . . . 10	Sands and clay, with foliated marls	Oxide of Iron, Flint, Glass-house Sand . . . . . 10	Marine Mollusca, Nummulites
		London clay and Bognor beds . . . . . 11	Brown and bluish grey clay, with septaria	Sulphide and Carbonate of Iron: Septaria: Selenite	Mammalia, Shells, Fishes, Chelonians, Crocodiles
TERTIARY.	LOWER.	Oldhaven, Woolwich, and Reading beds . . . . . 12	Freshwater sands, pebble beds, clay, rolled flints from chalk	Sulphide and Carbonate of Iron: Allophane . . . . . 12	Fluvio-Marine Mollusca, Fishes
		Thames sands . . . . . 13	Sands with concretionary masses of sandstone	Oxide of Iron, occasionally	Marine Mollusca

Table 126—continued.

SYSTEMS.	GEOLOGY.			MINERALOGY.	PALÆONTOLOGY.
	FORMATIONS.	GROUPS OF STRATA.	CHARACTERISTIC ROCKS.	PREVALENT MINERALS.	TYPICAL FOSSILS.
MESOZOIC.	CRETACEOUS <i>Upper.</i>	Upper chalk beds, with flints .. .. . 14	Soft white chalk, beds and nodules of flint	Flint, Pyrites, Hornstone, Allopbaue .. .. . 14	Marine Shells, Echinodermata, Sponges, Fishes
		Lower chalk beds, without flints .. .. . 15	Hard chalk, less white, generally without flints	Pyrites, Ochreous concretions .. .. . 15	Sponges, Cephalopoda, Foraminifera
		Chalk-marl or grey chalk beds .. .. . 16	Soft grey chalk, very clayey, sometimes indurated	Phosphate of Lime (Copolites) .. .. . 16	Shells, Echinodermata, Saurians
	<i>Middle.</i>	Upper Green Sand .. .. . 17	Siliceous and calcareous sand, nodules of chert	Siliceous concretions, Firestone, Chalcedony .. .. . 17	Ammonites, Sponges, Echinodermata, Marine Shells
		Gault .. .. . 18	Bluish marly clay, green grains, and sand	Phosphate of Lime (Copolites), Pyrites, Selenite .. .. . 18	Marine Shells, Belemnites, Ammonites, Saurians
	<i>Lower.</i>	Lower Green Sand, or Shanklin sand .. .. . 19	Green or ferruginous sands, layers of cherty limestone	Ironstone, Fullers' Earth .. .. . 19	Sponges, Cephalopoda, Crustacea
		Went clay and Hastings Beds .. .. . 20	Blue and brown strong clay, beds of shelly limestone	Petworth or Sussex Marble, Calcite .. .. . 20	Reptiles (Iguanodon), Fishes, Plants
	JURASSIC. <i>Upper, or Portland Oolite.</i>	Purbeck limestone .. .. . 21	Estuary limestones, clays and sands alternating	Calcite .. .. . 21	Fishes, Mammalia, Insecta, Reptiles, Trees, &c.
		Portland beds .. .. . 22	Oolitic and shelly limestone, layers of chert and sand	Chert, Calcite, Quartz-Crystals, Lignite .. .. . 22	Marine Shells, Corals, Saurians
		Kimmeridge clay .. .. . 23	Dark blue or black slaty clay, bituminous shale	Bitumen, Gypsum, Lignite, Pyrites, Alum-stone .. .. . 23	Marine Shells, Ammonites, Belemnites, Saurians
SECONDARY.	<i>Middle, or Oxford Oolite.</i>	Upper calcareous grit and clays .. .. . 24	Sands. Beds and nodules of calcareous grits	Calcite, Scapolite, Jet, Ironstone .. .. . 24	Ammonites, Marine Shells
		Coral flag and coralline .. .. . 25	Coarse oolitic limestone, with many corals	Calcite, Pyrites .. .. . 25	Corals, Marine Shells
		Lower calcareous grit and Limestone .. .. . 26	Sands. Beds and nodules of calcareous grits	Calcite, Pyrites, Hematite .. .. . 26	Ammonites, Marine Shells
	<i>Lower, or Bath Oolite.</i>	Oxford clay .. .. . 27	Dark blue clay, slaty and bituminous	Selenite, Pyrites .. .. . 27	Fishes, Shells, Belemnites, Ammonites, Saurians
		Kelloway rock .. .. . 28	Ferruginous coarse calcareo-siliceous limestone	Oxide of Iron, Calcite .. .. . 28	Marine Shells, Ammonites, Belemnites
		Cornbrash .. .. . 29	Coarse rubbly limestone, layers of clay, &c.	Oxide of Iron, Calcite .. .. . 29	Marine Shells, Ammonites
	<i>Lower, or Bath Oolite.</i>	Forest marble and Bradford clay .. .. . 30	Coarse shelly oolitic limestone and clay	Calcite, Chalcedony .. .. . 30	Ammonites, Shells, Brachiopoda, Eucrinites
		Bath, or great Oolite .. .. . 31	Thick-bedded oolitic limestone, free-stone	Rock-stone, Pisolite .. .. . 31	Corals, Shells, Nautili, Ammonites

Table 126—continued.

SYSTEMS.	GEOLOGY.			MINERALOGY.	PALÆONTOLOGY.
	FORMATIONS.	GROUPS OF STRATA.	CHARACTERISTIC ROCKS.	PREVALENT MINERALS.	TYPICAL FOSSILS.
MESOZOIC.	JURASSIC.	Stone-field slate .. .. 32	Oolitic shelly siliceous limestone, slaty	Pyritous Coal .. .. 32	<i>Monardia</i> , Reptiles
	Lower, or Bath Oolite.	Fullers' earth .. .. 33	Limestone and clay, containing Fullers' earth	Fullers' Earth, Gypsum .. 33	Marine Shells, Echinodermata
		Inferior Oolite .. .. 34	Coarse shelly limestone, or freestone	Calcite, Iron Ore .. .. 34	Marine Shells, Brachiopoda, Echinodermata
		Upper Lias shale.. .. 35	Dark-blue clay, alum shale, ferruginous sand	Bitumen, Alum. Jet .. .. 35	Marine Shells, Fishes, Saurians
	LIAS.	Middle Lias marlstone .. 36	Calcareous laminated sandy limestone, iron beds	Nodules of Ironstone, Sep- taria .. .. 36	Marine Shells, Ammonites, Belemnites
		Lower Lias, clays and lime- stone beds .. .. 37	Clay and limestone, alternating	Bitumen, Pyrites, Phos- phate of Lime .. .. 37	Saurians, Cephalopoda
		Penarth beds and white Lias .. .. 38	Estuarine (partly) shales, bone beds, &c.	Slates, Calcite, Cotham Marble .. .. 38	Bone-beds, Fishes, Shells, <i>First Monardia</i>
	BALEIC.	Keuper marl .. .. 39	Marls and sandstones, with rock salt and gypsum	Gypsum, Rock Salt .. .. 39	{ Few Fossils, <i>Foot-prints</i> , Estheria, Fish Few Fossils, Saurians
	TRIASSIC.	Dolomitic conglomerates of the Mendips .. .. 40	Red and white sandy limestone, con- glomerates with gypsum	Agates, Gypsum, Iron and Zinc Ores, Dolomite .. 40	
		Bunter sandstone and con- glomerates .. .. 41	Red clay and sand conglomerates and breccia	Hematite, Calcite .. .. 41	
PALEOZOIC.	PERMIAN.	Magnesian limestone .. 42	Fawn-magnesian limestone, some- times brecciated	Ores of Lead, Copper, Zinc 42	Marine Mollusca, Saurians
		Lower new red sandstone, conglomerates, marl .. 43	Highly ferruginous sands, marls, and conglomerates	Much Oxide of Iron, Agates 43	Marine Remains, Plants
	CARBONIFEROUS.	Coal measures (Ardwick, Pennant, and Gannister) 44	Coal-beds with layers of shale or grit	Anthracite, Splint, and Canuel Coal, Ironstone .. 44	Marine and Freshwater Mol- lusca, Ferns, Conifers
		Millstone grit and Yoredale Series .. .. 45	Siliceous sandstones and conglomer- ates. Fire-clay	Coal, Ironstone .. .. 45	Plants and Marine Mollusca
		Carboniferous limestone .. 46	Compact crystalline limestone and shales	Fluor, Ores of Lead, Zinc, Antimony, Iron .. .. 46	Marine Shells, Corals, Bryozoa, Cephalopoda
	DEVONIAN.	Upper Devonian, Marwood, Petherwin limestone .. 47	Yellow, white, and red sandstones and conglomerates	Agates, Ores of Tin, Copper, and Lead and Zinc .. 47	Corals, Brachiopoda, Ganoid Fishes and Plants
		Middle Devonian, Lime- stones and Shales .. .. 48	Green and red shales and sandstones, with corals	Iron Ore, Calcite, Marble .. 48	Corals, Brachiopoda, Ganoid Fishes and Plants
		Lower Devonian, Linton and Fowey beds .. .. 49	Red shales, sandstones, and conglom- erates. Tilestones	Firestone, Chalcedony, Ores of Copper and Tin .. 49	Marine Mollusca, Ganoid Fish and Plants
PRIMARY.	CARBONIFEROUS.				
SECONDARY.	TRIASSIC.				

Table 126—continued.

GEOLOGY.			MINERALOGY.	PALÆONTOLOGY.
SYSTEMS.	FORMATIONS.	GROUPS OF STRATA.	PREVALENT MINERALS.	TYPICAL FOSSILS.
PALEZOIC.	SILURIAN.	Upper Ludlow shale—Ludlow Rocks .. .. . 50	Barytes, Calcite, Copper, Lead and Manganese Ores 50	Mollusca, Brachiopoda, Graptolites, Fish
		Lower Ludlow shale—Ludlow Rocks .. .. . 51	Calcite, Copper, Lead and Manganese Ores .. 51	Marine Mollusca
		Wenlock and Dudley limestone—Wenlock Rocks .. 52	Calcite, Copper, Lead and Manganese Ore .. 52	Marine Mollusca, Trilobites
		Wenlock slate and Denbigh grit—Wenlock Rocks .. 53	Calcite, Copper, Lead and Manganese Ores .. 53	Brachiopoda, Ecnurites, Bryozoa, Crinoids
		Woodhope and Barr Limestone—Wenlock Rocks .. 54	Calcite, Copper, Lead and Manganese Ores .. 54	Marine Mollusca
		Tarannon slates .. .. 55	Calcite, Copper, Lead and Manganese Ores .. 55	Coral, Trilobites, Graptolites
		Upper Llandovery (May Hill Sandstone) .. .. 57	Calcite, Copper, Lead and Oxide of Iron. Copper, Lead and Manganese Ores .. 57	Marine Mollusca
		Lower Llandovery sandstone .. .. . 58	Ores of Lead and Copper, Gold .. .. . 58	Marine Shells, Corals, Trilobites
		Cardo and Bala beds .. 59	Ores of Lead, Copper and Iron, Gold, Silver .. 59	Corals, Trilobites, Brachiopoda
		Llandovery Flags (upper and lower) .. .. . 60	Ores of Lead, Copper, and Iron, Barytes .. .. 60	Trilobites, Brachiopoda, Graptolites
AZOIC.	CAMBRIAN.	Trinacrolepis slates? Graptolite slates .. .. . 61	Ores of Lead, Copper, and Iron .. .. . 61	Graptolites, Brachiopoda
		Lingula flags (upper and lower). Merneian beds 62	Ores of Lead, Copper, and Zinc, Gold, Silver .. 62	Brachiopoda, Trilobites, Lingulæ
		Harlech and Llanberis slates, and Longmynd grits .. 63	Barytes, Ores of Copper, Silver and Lead, Gold .. 63	Fucoids, Trilobites
		St. David's and Anglesea Rocks .. .. . 64	Quartz, Graphite, Apatite, Iron & Copper Ores, Gold 64	Worm-tubes
		Gneiss, &c., rudely stratified 65	Garnet, Asbestos, Ores of Tin, Lead & Copper, Gold 65	No fossils yet discovered
		Granite, &c., unstratified .. 66	Quartz, Feldspar, Talc, Actinolite, Hornblende, Albite, Ores of Tin & Lead, Gold 66	No fossils yet discovered

PRIMARY

## GEOLOGICAL MAPS.

## GEOLOGICAL SURVEY MAP SIGNS.

## (a) Connected with Stratification.

+	Horizontal.
⊥	Vertical (longest line on the strike).
×	Undulating.
∞	Contorted.
↓	Highly inclined
↗ ↘	Undulating
↗ ↘	Contorted
↗ ↘	Anticlinal axis.
*	Synclinal axis.
↓	Dip from observation (with No. of degrees, thus ∠ 5°).
↗ ↘	Dip from information.
/	Cleavage.
⊙	Limestone quarries.
S. Q.	Slate quarries.

*Interrupted Lines* = A doubtful or drift-covered boundary.

*White Lines* = Faults at the surface.

*Yellow Lines* = Faults underground.

*Thick Black Lines* = Coal crops. When doubtful, lines interrupted.

○ Bore hole.






⊖ Mine shaft.

⛑ DH Day hole (entrance to adit).


== Colliery levels.

*Survey Signs—continued.*

## (b) Connected with Glacial Drift.

	Roches moutonnées.		
	"	striated	} Direction of Ice-flow not apparent.
	Flat surface	"	
	Roches moutonnées	"	} Showing direction of Ice-flow.
	Flat surface	"	

## (c) Indicating Ores of Metals.

	Gold.		Silver.
	Copper.		Tin.
	Lead.		Manganese.
	Iron.		Zinc.

*Gold Lines* = Mineral Veins.*Gold Dots* = Stream Tin.*Gold Rings* = Pipe Veins.



## MINERAL VEINS.

Table 127.—*Dip, Depth, and Thickness of Beds.* (Penning.)

Amount of Dip.	Co-tangent of Angle of Dip.	Approximate Proportionate Incline.	Yards of Rise or Fall in 1 mile.	Vertical Depth from Surface in a Horizontal Distance of 100.	Thickness of Beds at right angles to Plane of Stratification.
0	Infinity.				
1	57.29	1 in 57	31	1.75	1.75
2	28.6363	1 in 28½	61	3.5	3.5
3	19.0811	1 in 19	92	5.25	5.25
4	14.3007	1 in 14½	126	7.	7.
5	11.4301	1 in 11½	155	8.75	8.75
6	9.5144	1 in 9½	185	10.5	10.5
7	8.1443	1 in 8	217	12.5	12.25
8	7.1151	1 in 7	249	14.	13.75
9	6.3138	1 in 6½	279	16.	15.75
10	5.6713	1 in 5½	314	17.5	17.25
11	5.1445	1 in 5	345	19.5	19.25
12	4.7046	} 1 in 4½	391	21.25	20.75
13	4.3315			23.25	22.5
14	4.0108	1 in 4	440	25.	24.
15	3.7321	} 1 in 3½	..	26.75	25.5
16	3.4874			28.5	27.
17	3.2709	} 1 in 3	..	30.	28.25
18	3.0777			32.25	30.25
19	2.9012	} 1 in 2½	..	34.5	32.
20	2.7475			36.5	33.5
21	2.6051	} 1 in 2	..	38.5	35.
22	2.4751			40.	36.
23	2.3559	} 1 in 1½	..	42.25	37.75
24	2.2460			44.5	39.5
25	2.1445	} 1 in 1¼	..	46.75	41.25
26	2.0503			47.75	41.75
27	1.9626	} 1 in 1⅓	..	51.	44.25
28	1.8807			53.25	45.75
29	1.8010	} 1 in 1⅔	..	55.5	47.25
30	1.7321			58.	49.
31	1.6613	} 1 in 1⅞	..	60.25	50.5
32	1.6003			62.5	51.75
33	1.5399	} 1 in 2	..	65.	53.25
34	1.4826			67.5	54.75
35	1.4281	} 1 in 2¼	..	70.	56.25
36	1.3764			72.5	57.75
37	1.3270	} 1 in 2½	..	75.25	59.5
38	1.2799			78.	61.

Table 127—continued.

Amount of Dip.	Co-tangent of Angle of Dip.	Approximate Proportionate Incline.	Yards of Rise or Fall in 1 mile.	Vertical Depth from Surface in a Horizontal Distance of 100.	Thickness of Beds at right angles to Plane of Stratification.
0					
39	1.2349	} 1 in 1	}	81.25	63.
40	1.1918			84.	64.5
41	1.1504			87.	65.75
42	1.1106			90.	67.75
43	1.0724			93.	69.25
44	1.0355			96.	70.25
45	1.			100.	71.
46	.9657			104.	72.
47	.9325			107.	73.25
48	.9004			111.	74.25
49	.8693	}	}	115.	75.5
50	.8391			119.	77.
51	.8098			123.	78.
52	.7813			128.	79.
53	.7536			133.	80.
54	.7265			137.	81.
55	.7002			143.	82.
56	.6745			150.	83.
57	.6494			154.	83.25
58	.6249			161.	84.5
59	.6009	}	}	166.	85.5
60	.5774			172.5	86.5
61	.5543			180.	87.
62	.5317			188.	88.
63	.5095			200.	89.
64	.4877			205.	90.
65	.4663			213.	90.5
66	.4452			224.	91.
67	.4245			235.	91.5
68	.4040			250.	92.
69	.3839	}	}	260.	93.
70	.3640			275.	94.
71	.3443			300.	94.5
72	.3249			308.	95.
73	.3057			327.	95.5
74	.2867			345.	96.
75	.2679			370.	96.5
76	.2493			400.	97.
77	.2309			433.	97.5
78	.2126			476.	97.5
79	.1944	}	}	515.	98.
80	.1763			570.	98.5
81	.1584			633.	98.5
82	.1405			714.	99.
83	.1228			813.	99.
84	.1051			1000.	99.5
85	.0875			1140.	99.5
86	.0699			1430.	99.5
87	.0523			1912.	100.
88	.0349			2865.	100.
89	.0175	}	}	5714.	100.
90	.0000			—	100.

*Dip, Depth, and Thickness.*

*Ex. 1.* The outcrop, in a level district, of a definite bed is observed in a quarry, where it is found to dip E. at an angle of  $14^{\circ}$ . This bed would be found, if its dip remains unaltered, 100 yd. east from the quarry at a depth of 25 yd. = 75 ft.; the beds above it would have an actual thickness of 24 yd. = 72 ft.

*Ex. 2.* The outcrop of the same bed with the same dip is observed in a district where the surface rises in the direction of the dip at an angle of  $10^{\circ}$ . The bed would be found, 100 yd. E. at a depth of 75 ft., as before, plus the rise in the ground between, which in 100 yd., at the rate of 314 yd. in a mile, is  $17\frac{2}{3}$  yd. = 53 ft.:— $75 + 53 = 128$  ft. If the ground were falling, instead of rising, at an angle of  $10^{\circ}$  in the direction of the dip, the bed would be met with at  $75 - 53 = 22$  ft.

*Ex. 3.* A bed or formation is known to be 36 yd in thickness, and to dip at an angle of  $14^{\circ}$ . In 100 yd. of outcrop it would, at that dip, have a thickness of 24 yd. only, therefore its outcrop is ( $24 : 36 :: 100$ ) : 150 yd.

*Ex. 4.* The thickness is known to be 36 yd. as before, and the level outcrop 150 yd. In 100 yd. ( $\frac{2}{3}$  of 150), the thickness would be 24 yd., which corresponds to a dip of  $14^{\circ}$ .

*Ex. 5.* The dip of the bed is  $14^{\circ}$ , its outcrop 150 yd.; in 100 yd. at  $14^{\circ}$  the thickness would be 24 yd., therefore in 150 it is 36 yd.

MINERAL VEINS: *Contents of Veins.*

A vein of ore 1 in. thick, 6 ft. long, and 6 ft. high (= 1 sq. fathom) will measure 3 cub. ft.; 2 in. thick = 6 cub. ft. per fathom; and so on.

Table 128.—*Weights of Ores 1 in. thick per sq. fathom (i. e. per 3 cubic ft.).*

	lb.		lb.
Antimony, grey oxide .. ..	843	Iron, magnetic .. ..	1016
Barytes .. ..	750	„ pyrites .. ..	912
Cobalt, pyrites .. ..	937	„ specular .. ..	912
Copper, carbonate (malachite) .	712	Lead, carbonate .. ..	1200
„ grey .. ..	900	„ sulphide (galena) .. ..	1406
„ native .. ..	1668	Nickel, arsenical .. ..	1406
„ pyrites .. ..	787	Silver, native .. ..	1875
„ red .. ..	1106	Tin, oxide .. ..	1256
„ vitreous .. ..	1050	„ pyrites .. ..	825
Gold, native .. ..	3281	Uranium, oxide (pitchblende) .	1312
Iron, arsenical .. ..	1068	Zinc, red oxide .. ..	1012
„ hematite .. ..	750	„ sulphide (blende) .	750

The above figures  $\times 9$  = weights per cub. yd.

Table 129.—*Weights of Rocks per cub. ft.*

	lb.		lb.
Basalt .. .. .	187	Limestone, Portland .. ..	131
Chalk .. .. .	143	Marble .. .. .	168
Clay .. .. .	125	Sand .. .. .	120
Granite .. .. .	164-172	Sandstone .. .. .	130-157
Gravel .. .. .	120	Shale .. .. .	162
Grit .. .. .	131	Shingle .. .. .	90
Limestone .. .. .	156-175	Slate .. .. .	175-180
" Bath .. .. .	112	Trap .. .. .	170
" magnesian .. ..	178	York flags .. .. .	143

MINERAL VEINS: *Examination of Wall Rocks of Auriferous Fissures.* (Attwood.)

The mere inspection of the outer surface of a rock, viewed as an opaque object, does not give such correct information as that obtained when the examination is made by transmitted light, and with the aid of the microscope; yet, if the examination is properly conducted, it will afford all the necessary information required by the miner to enable him roughly to distinguish the character of the enclosing rocks of most auriferous fissures, especially if the rocks should be of a coarse texture.

In the macroscopical investigation of rocks, those parts of the mineral constituents discernible by the naked eye, or by the aid of a common magnifier, can be easily studied, with reference to crystalline form, cleavage, colour, lustre, streak, hardness, solubility in acids, magnetic properties, &c. The specimen of rock selected for examination should have a good fresh surface of fracture, and be free from decomposition; size, about 3 by 4 in. across, and  $1\frac{1}{2}$  in. through. With a trimming hammer, prepare the  $1\frac{1}{2}$  in. face, or dress it as even as possible; then procure an iron plate, with a smooth face about 10 in. square and  $\frac{1}{2}$  in. thick, on which put emery powder No. 80 and water; rub the prepared face of the specimen upon it till it is smooth enough to polish. This can be done by getting a piece of thick glass, about same size as the iron plate, on which put fine emery and water, and again rub the specimen till you obtain a fine polish. When polished, heat the specimen on a stove so that you can barely handle it, and when in that condition rub Canada balsam over *half* the polished surface. When cold it will harden so that it can be handled without injury. A small fragment may be broken from the unpolished end to try its specific gravity, magnetic properties, and also for acid tests.

The following implements will be found sufficient for this simple mode of investigation:—

1. A common magnifier mounted in horn, that being lighter than metal; it should have three powers, and be set in a spectacle frame with screws, so that the different powers can be easily changed.

*Wall Rocks—continued.*

2. A small bar magnet, and also a magnet needle freely suspended or supported.
3. A small unglazed porcelain streak plate.
4. A bottle of hydrochloric acid, with a fine glass rod attached to the stopper.
5. A dressing hammer, with the head about 3 in. long; one end with a face  $\frac{1}{2}$  in. square, and the other chisel shaped.
6. A pocket micrometer, same as made by Lietz, San Francisco.
7. A piece of flat iron, 10 in. square and  $\frac{1}{2}$  in. thick.
8. A piece of thick glass, 10 in. square, and a few lb. of coarse and fine emery.
9. Scale of hardness.

The best mode of determining the hardness is to have the minerals forming the scale of hardness mounted, something like the writing diamond. Break, for instance, the corundum, topaz, &c., into small fragments, and after selecting those with fine, sharp points, proceed to mount them as follows:—

Take a piece of brass wire 3 in. long by  $\frac{1}{8}$  in. diameter, and with a file make small notches on one end of the wire; then take "lapidary's cement," warm the end of the wire with a spirit-lamp or candle, and melt some of the cement on to it. By wetting the finger and rubbing the cement while warm, it can be moulded into any shape desired. With a small pair of pliers take the small fragments of corundum, &c., heat one end of the corundum, and then place it in the cement. If this be properly done, it will answer just as well as if set in metal, with this advantage, that you can renew it at any time in a few moments.

In addition to the implements named, a small collection of the commoner types of rocks should be procured, and prepared with polished sides, after the manner before described.

The specimens of igneous rocks should consist of granite, syenite, diorite, gabbro, diabase, dolerite, and basalt, and of small bottles with fragments of the different felspars, showing character and cleavage; orthoclase (potash felspar), albite (soda), anorthite (lime), labradorite (lime soda); also small pieces of hornblende and augite.

The triclinic felspar may be distinguished from monoclinic, *e. g.* oligoclase or labradorite from orthoclase, by the presence of fine parallel striae along the surface of certain of the cleavage planes. Hornblende crystals have generally a fibrous structure, by which they may often be recognised from augite crystals.

It will also be necessary to have a few specimens of metamorphic, crystalline schists, sedimentary and fragmental rocks. With the small collection of the already named characteristic rocks for comparison, the rough determination of hand specimens of enclosing rocks may easily be arrived at. The coating of Canada balsam shows the structure and crystalline character much better than the ordinarily polished surface, so that the tests for hardness, &c.,

*Wall Rocks*—continued.

should be applied only to the polished surface. By having the lenses set in spectacle frames both hands are at liberty, one to hold the rock, the other to use the scale of hardness, or to apply the fine glass rod dipped in acid to try if any of the component parts of the specimen effervesce. These tests for comparison can be applied to those types in the collection which resemble the one being tested. The magnetic properties can be tested with a freely suspended magnetic needle, or by breaking a portion of the rock into small fragments, washing it in a lutea, and then applying the bar magnet to the heavier particles. The size of the crystals may be measured with a pocket micrometer. The macroscopic inspection of rocks made by cutting large slices and polishing their faces is strongly to be recommended to all miners and prospectors as of the highest importance.

Table 130.—*Igneous Rocks classified, primarily, according to their Mineralogical Composition; and, secondarily, according to their Intimate Structure.* (Prof. Bonney.)

	Matrix Wholly Crystalline.	Matrix Semi-Crystalline.
1. Orthoclase felspar.		
a. Quartziferous ..	Granite .. ..	Quartz-felsite ..
b. Quartzless ..	Syenite .. ..	Orthoclase-felsite, minette.
		Quartz-trachyte. Sanidin - trachyte, pitchstone, and obsidian.
2. Plagioclase felspar.		
a. Oligoclase, some- times with quartz	Diorite .. ..	Porphyrite .. ..
b. Labradorite, or an allied mineral or quartz.	Gabbro, dia- base, dolerite, basalt.	Some basalts ..
		Andesite. Tachylite.

*Indicative Plants.*

From very early times it has been noticed that the soil overlying mineral veins is favoured by special vegetation, and though the occurrence of such vegetation cannot be taken as an infallible indication of the existence of such veins, it will be interesting to record the results of past observations, so that they may serve for a guidance to further observation in future.

*Iron.*—A vein of iron ore near Siegen, Germany, can be traced for nearly 2 miles by birch trees growing on its outcrop, while the remainder of the country is covered with oak and beech.

*Lead.*—The "lead plant" (*Amorpha canescens*) is said by prospectors in Michigan, Wisconsin, and Illinois to be most abundant in soils overlying the irregular deposits of galena in limestone.

*Indicative Plants—continued.*

It is a shrub 1-3 ft. high, covered with hoary down; the light blue flowers are borne on long spikes, and the leaves are arranged in close pairs on stems, being almost devoid of footstalks.

Gum trees or trees with dead tops, as also sumac and sassafras, are observed in Missouri to be abundant where "float" galena is found in the clays.

*Limestone.*—The beech tree is almost invariably prevalent on limestone, and detached groups of beech trees have led to discoveries of unsuspected beds of limestone.

*Phosphate.*—The phosphate miners in Estremadura, Spain, find that the *Convolvulus althæoides*, a creeping plant with bell-shaped flowers, is a most reliable guide to the scattered and hidden deposits of phosphorite occurring along the contact of the Silurian slates and Devonian dolomite.

*Silver.*—In Montana, experienced miners look for silver wherever the *Eriogonum ovalifolium* flourishes. This plant grows in low dense bunches, its small leaves coated with thick white down, and its rose-coloured flowers being borne in clusters on long smooth stems.

*Zinc.*—The "zinc violet," *Galmereilchen*, or *Kelmesblume* (*Viola calaminaria*) of Rhenish Russia and neighbouring parts of Belgium, is there considered an almost infallible guide to calamine deposits, though in other districts it grows where no zinc ore has been found. In the zinc districts its flowers are coloured yellow, and zinc has been extracted from the plant. The same flower has been noticed at zinc mines in Utah.

*Ore Deposits.*

The primary source from which metalliferous veins have been derived, and the causes which determined the peculiar metal or metals in each case, are matters about which we know nothing. But the manner in which these deposits have been formed comes within the bounds of reasonable conjecture, and has an important bearing upon the commercial value of the deposit, especially as regards its bulk and permanence.

There is abundant evidence in favour of the opinion that all the principal accumulations of useful ores are due to the precipitation of material collected by water in its passage through rocks at various depths, the mineral being very sparsely and widely distributed, dissolved by the water under the influence of considerable heat, and subsequently concentrated and precipitated in favourable situations. These latter were less likely to have been large cavities than narrow spaces, though occasionally there may have been wide areas awaiting the influx of vein matter. But it seems quite as likely that where large veins occur these are in great measure composed of altered country rock, and owe only a small portion of their contents to extraneous sources. Assuming this origin of metallic veins to be correct, then a knowledge of the geological

*Ore Deposits—continued.*

structure of the district, as bearing upon the formation of the water passages which introduced the metalliferous solutions, is of great significance to the mining engineer.

This subject has been very thoroughly dealt with by S. F. Emmons, of the United States Geological Survey, and the following remarks are condensed from his published papers. The three principal structural conditions which would produce natural water-passages in the rocks forming the earth's crust are:—

- (a) Sedimentation or bedding.
- (b) Intrusion of eruptive masses.
- (c) Dynamic movements producing fractures across rock-masses of differing origin or composition.

(a) By the first of above causes, by the deposition of alternating strata of varying degrees of permeability, or by successive flows of igneous rocks, natural channels will be afforded parallel to the stratification or bedding-planes, and more or less coincident with them according to the nature of the material of which the bounding beds are formed.

These primary water-channels along bedding-planes may be interrupted by either of the two causes *b c*.

(b) Eruptive dikes or cross-cutting intrusive bodies of any form may interpose relatively impermeable masses across their course, or intrusive bodies, running parallel with the bedding, may render the plane of contact a more ready water passage than it otherwise would have been.

(c) The interruption to these primary water-channels resulting from the varied forms of rock-fracture caused by dynamic movements are manifold and numerous.

The greatest number of underground water-channels, though perhaps not those carrying the largest volumes of water, will be afforded by the multitudinous fractures in the crystalline or eruptive rocks, and in the older and more metamorphosed sedimentary strata.

Another possible class of division-planes in rocks are contraction-planes or joints, notably the prismatic joints of more recent eruptives. Contraction-planes must be confined to one rock-mass or bed, and cannot cross several of them, as do most mineral-bearing fissures. Also, as contraction-planes alone, there would have been no movement or pressure along them. Hence planes where evidences of movement or pressure are found cannot result from contraction alone.

*Ore-deposits along bedding-planes.*—Most ore-deposits are found in mountainous regions where eruptive and dynamic action has been energetic; consequently, deposits resulting from the flow of water along bedding-planes alone, unconnected with the other classes of water-channels, form but a small proportion of the whole. Moreover, deposition will take place more readily from a comparatively



*Ore Deposits—continued.*

sluggish than from a rapid flow; hence conditions that tend to retard the flow or cause a partial stagnation at a given point will favour precipitation at that point. Such would be the actual contact of an impervious stratum, *e. g.* a bed of clayey material—with a readily pervious one like a loose sandstone. Again, in plicated strata, points where by sharp folding the beds are closely compressed together—as on the side of the fold—are often found to carry large bodies of ore. The chemical composition of the different beds is also a most important factor. In some regions, where thin beds of limestone are scattered through considerable thicknesses of sandstone and shales, the ore is almost exclusively confined to the more readily attackable limestone.

*Deposits along contact-planes.*—Mineral-bearing solutions gathering in or flowing along the planes of contact of eruptive bodies with rocks through which they had been forced would have a tendency to deposit their contents along such planes, whatever the direction of their flow. If they were ascending currents, it may be conceived that they were coming from a hotter region, or from the vicinity of a larger and not so thoroughly cooled mass of igneous rock, where their solvent power was greater, to a cooler region in which this solvent power would be relatively less. If lateral or descending flows, gathering from the mass of one of the walls of the fissure, precipitation might be induced from the solutions thus brought in by a retardation or temporary stagnation of the flow, by dilution through mixing with other waters already circulating in the fissure, or by some chemical interchange resulting from contact with the other wall, if a rock of different chemical composition from that through which the solutions had been passing.

Contact-planes as defined above will more frequently be found to coincide or connect with planes of rock-fracture, since one can hardly conceive of sheets of eruptive rock being forced through existing rock-masses in the form in which we now find them, unless they had followed some already determined line of fracture, or at least of readiness to be forced open, and it is well known that eruptions of lava at the present day are generally preceded by earthquake shocks, which probably involve a very considerable shattering and fissuring of the earth's crust in the vicinity of the eruption.

Ore-deposits along contact-planes are very common. Of deposits along the contacts of dikes or cross-cutting bodies of eruptive rock, hence generally occupying a more nearly vertical position, abundant examples are found, most of which are commonly classed by the miner as fissure-veins, because of the prevailing prejudice in favour of the supposed greater value of that type of deposit. It may be that the whole mass of a narrow dike is impregnated with mineral, and thus constitutes the ore-body; but in the structural sense it is none the less a contact-deposit, since the deposit has been made by waters acting from the contact-planes outward.

*Ore Deposits—continued.*

*Deposits along planes of rock-fracture or fissures produced by dynamic movements.*—The most prominent and readily remarked of these rock-fractures are the great faults which have played so important a part in determining the orographic relief of our globe. The greatest of these faults often extend for miles in length, and the displacement of the opposed rock-masses on either side of the fault may amount to several thousand feet. Minor faults, or displacements which are found in infinite variety, especially in regions of great dynamic disturbance, may not produce any readily apparent effect upon the surface-features, and yet may be recognisable as determining the flow of springs, or be detected by the underground workings of mines. They have been most thoroughly studied in the workings of coal-mines, where the importance of careful underground mapping is most generally appreciated, since the determination of the direction and amount of throw of such faults has an actual money-value. In all these rock-fractures the evidence of a movement of displacement, as disclosed by the discrepancy or want of correspondence in the adjoining walls, is usually very prominent. There are other and much more numerous rock-fractures, in which there is either no movement of displacement, or it is so slight as to be with difficulty detected. Among them certain classes are characterised by their frequency and their general parallelism in two or more co-ordinated directions, and at angles often approaching a right angle with each other.

*Causes of Fracture.*—It is hardly necessary to state that the force which produces the folding, faultings and rock-fractures, in short the mountain-building force, must be considered as a result of the secular construction of the earth's crust, the forces exerted resulting from the attempt of an already consolidated crust to fit itself more closely to a shrinking nucleus. Their effect is felt probably only upon a comparatively thin outer portion of the earth's crust: at any rate it is a very thin portion of this crust which comes under our observation. This crust may be conceived, therefore, as having been since its first formation in a condition of tension, a gradually increasing force which from time to time found its relief in earth-movements producing corrugations on its surface, and hence relative elevations along certain orographic lines, which from some reason or other were lines of least resistance or of weakness. Such lines, once determined, have been the scene of most marked expression of these constantly recurring movements of relief from tension. Closely connected with such movements have been the eruptions of igneous material, forced up from below, either from a region of permanent fusion of the material of the earth's crust, as was formerly most generally maintained, or, according to later views, from local reservoirs brought into a fused condition as a more or less direct result of these movements, by the disturbance of equilibrium between the various forces involved in the general condition of tension. Whatever their source, the eruptions of igneous rocks

*Fractures—continued.*

have unquestionably had a very close connection with orographic disturbances, and further have indirectly played an important part in the formation of most ore-deposits.

Observation teaches us that these successive periods of dynamic disturbance, or of mountain-building, must have been followed by periods of relative quiescence, during which the regions elevated into land-masses were worn down by atmospheric abrasion, and their comminuted debris carried into the adjoining oceans to form a new series of sedimentary beds. Each successive series of dynamic movements would involve not only this newer series, but also the older and already plicated and fractured series of rocks; and thus the structural conditions are found to be more complicated and more difficult to decipher, the older the rocks in which we have occasion to study them.

*Common characteristics of compression-fractures.*—There are three phases of structural evidence of rock-fractures and displacement resulting from compression, one or more of which characterise the various types of fissures carrying ore-deposits. These are:—

(a) Striations and “slickenside”-surfaces.

(b) Breccia or fragmentary material in the fissure itself, or zones of crushed or broken rock-material included between intersecting systems of fissures.

(c) A sheeting of the country-rock parallel with the main fracture: in other words, the occurrence of a system of minor fractures which divide the country-rock up into a system of approximately parallel plates or sheets. The distance between these parallel fractures, or the thickness of the sheets, may be reckoned by inches, by feet, or by hundreds of feet, according to the varying texture of the rock-masses involved, or the different dynamic conditions which have produced the fracture.

It will at once suggest itself that these are all phenomena characteristic of faults. But they are also found, at times, where there may be no recognisable evidence of actual displacement of the rock-masses on either side of the fissure or fracture. On the other hand, it will be equally evident that fissures characterised by these phenomena can hardly be the result of contraction, or shrinkage-cracks.

Striations are not confined to well-defined fissures, but are found on smaller planes within rock-masses; but in any case they seem to necessarily give evidence of movement under pressure, be the amount of that movement ever so small.

Fragments of country-rock are often rounded. These have less probably fallen into the fissures from the walls, and become rounded by attrition either against the walls or against each other, than been produced by the rubbing or dragging of one wall against the other. The greater or lesser size of the fragments would, in a measure, prove a greater or less distance between the walls, but it seems that under the enormous pressure that must have accom-

*Fractures—continued.*

panied these rock-fractures, the space between the walls must have been more or less completely filled with attrition material, only part of which would be actual rock-fragments, and the rest finely comminuted material, which, under the dissolving agency of percolating waters, would finally result in more or less impure clays. The rounding of the fragments, on the other hand, is readily accounted for as the action of these same percolating waters, it being a well-recognised fact that the decomposing action of moisture in any form acts more rapidly on the corners or angles of a rock-mass than on its flat surfaces, and the sharper the corner the more rapidly is it eaten away.

Crushed zones are merely larger phases of the same actions as produce the breccia-material, and are subject to the same general laws, only differing in their greater dimensions and the more irregular shape of the enclosing walls.

The sheeting of the country-rock in faulted or fractured regions where ore-deposits abound is a phenomenon to which hitherto too little attention has been paid. Its importance as a feature of fissure-veins is, however, great both from a geological and from a practical point of view. That it has hitherto escaped due recognition is probably due to the prevalence of the old idea that vein-deposits are necessarily the filling of open fissures, and to the failure to appreciate to how great an extent they are actually the replacement of rock-material rendered more readily accessible and attackable by the dynamic movements which produced the fissure.

From individual fissure-faults there is a gradual transition into co-ordinated fractures, as a rule greater in number in a given area, but of less individual extent, which form a sort of fractured zone with two or more prominent directions of fracture, apparently of nearly contemporaneous formation. These Emmons calls *compression-joints*, because they always show one or more of the evidences of compression, viz. striation, brecciation or crushed material, and sheeting of the country-rock. Such complicated systems of fracture would appear to involve the action of more than one system of dynamic movement; that is, of forces of compression acting at the same time in different directions, and hence combining with the direct plicational strain more or less strain of torsion.

In the larger joints or fractures observed in mining districts, the effects of direct compression have been more marked, and the effects of the torsional strain are probably more seen in the minor fractures, or stringers and leaders, as the miners call them. In the map of a mining district characterised by a multitude of small veins, it will be found that the more detailed the map and the more thoroughly the veins have been explored and represented thereon, the more regularity and uniformity in their directions are shown. It must be borne in mind, however, that such a map never represents the totality of the fissures in the district, but only such parts of them as have been found sufficiently rich to exploit for ore.

*Fractures—continued.*

It is evident that by a succession of dynamic movements, especially when accompanied by torsional strains, an almost infinite variety of fissures and passages for mineral-bearing waters may be produced, and that it would therefore not be possible beforehand to describe all the various structural conditions under which ore-deposits may occur. But certain conditions suggest themselves as a result of the structural method of considering them that would seem to have a general application.

*Structural Generalisations.—Extent of Fissures.*—Since the dynamic movements are confined to the crust of the earth, it is evident that the fissures produced by them cannot literally have an indefinite extent in depth, though in certain cases it is very possible that this extent may be practically indefinite, as it may go beyond the limits at which mining is practicable. It is fair to assume that those fissures which have the greatest horizontal extent will have the greatest extent in depth; in other words, that their vertical and horizontal dimensions bear some sort of proportion to each other. If, therefore, as some have maintained, the vein-filling has in all cases been brought from some source at great depths in the earth, the greatest fault-fissures would be expected to be the greatest and most frequent ore-producers, since they would reach nearer to this unknown source.

But rather the reverse is the case, which, as far as it goes, furnishes an argument in favour of the view that the vein-material has been derived from the surrounding, though not of necessity absolutely contiguous, rocks. On the great fold-faults are found no considerable deposits of ore, and it is comparatively rare that continuous deposits are found along a single well-defined fault-fissure. The majority of deposits seem to occur where there are a series of fissures, more or less regularly co-ordinated, in which several of the series are prominently accentuated. In such systems there seems to be a tendency for the rich ore-bodies or bonanzas to extend in a direction which lies at an angle with that of the main fissure, or to continue for a certain distance along one fissure and then to pass into another fissure, set off at a little distance from the first. It would seem probable that there must be some structural reason for the concentration of ore in this way. The practical lesson to be learned is that the miner should not confine his explorations to the single fissure in which his ore occurs, but when he runs out of bonanza in that, he should seek a continuance of it in some adjoining fissure or plane, in a direction to be determined by the study of the system of the fracturing of the region and of the general direction of the bonanzas.

*Vein-walls.*—The second generalisation is in regard to the *walls*, which have generally been considered an important and almost indispensable characteristic of a true fissure-vein. The typical wall which the miner considers an evidence of a strong and well-defined fissure-vein is a comparatively smooth, generally striated,

*Structural Generalisations—continued.*

rock-plane, and frequently coated with a clay selvage—a band of decomposed argillaceous material which itself generally shows evidence of pressure and movement. From the above structural point of view of the origin of vein-fissures it is evident that the character of the wall and selvage is dependent on the composition of the rock and the amount of displacement and pressure. The grinding of one face of rock against another will undoubtedly tend to plane both off and to produce a certain amount of fine attrition-material; but this attrition-material will not necessarily be reduced to clay unless it has further been subjected to the decomposing action of water, which has carried off certain portions and left an argillaceous residue. The extreme instance of such decomposition is found in the muddy accumulations at the bottom of caves in limestone, which are simply the less soluble residues, mostly silica and alumina, resulting from the dissolution of large quantities of more or less impure limestone.

These walls and selvages are a frequent accompaniment, but by no means an essential characteristic, of an ore-bearing fissure. It is quite conceivable that one or both may be wanting; and such occurrences are not uncommon in nature. Take, for instance, the veins of Butte, Montana. These are a series of co-ordinated fractures or compression-fissures in a remarkably homogeneous mass of granite. Apparently there has been little or no displacement of the walls of these fissures relatively to each other; hence, but little attrition-material has been produced; and for this reason—and probably, also, on account of the character of the rock and because it was not much decomposed along the fissure-planes before the advent of the ore-bearing solutions—no clay selvages have been formed, and the ore-bearing solutions have eaten into the wall-rock to varying distances, replacing it more or less completely by vein-material, and leaving no definite boundaries or walls to the deposits. There is no reason, however, for considering them any the less true fissure-veins or less valuable ore-deposits on this account.

On the other hand, under certain conditions, instead of an absence of well-defined walls there may be so many as to mislead the miner who depends too implicitly upon them as a boundary of his ore-body. In the Gunnison region, for instance, where, owing to the plasticity of the country-rock, it has been divided along the main fracture-planes into a series of very thin parallel sheets, the space between these sheets has frequently been filled by quartz, which thus forms a thin sheet, often so completely reproducing the form of the fissure as to present a cast of the striation-surfaces. Such a sheet of quartz, when the adjoining bands of country-rock have been replaced by vein-material, forms a hard, well-defined wall to the ore-body, which delights the eye of the honest miner and enhances in his mind the value of his property.

Ore may be found as well on one side as on the other of such a wall, and not unfrequently is apparently confined to one side for a

*Structural Generalisations—continued.*

considerable extent along the length of the vein, and then is found almost as exclusively on the other side. In one prominent instance a new body of rich ore was struck by cross-cutting into the foot-wall country. The moral is that judicious cross-cutting forms a very important part of vein-mining, but should be conducted with due regard to the fracture-system of the adjoining country, and to the evidence to be obtained as to the course followed by the ore-bearing currents, or it may involve an unnecessary amount of dead work.

*Banded structure.*—In most of the deposits of the Gunnison region, there is a noteworthy appearance of banded structure parallel with the walls of the fissure. The evidence of faulting and of the thin sheeting of the country-rock is there so clear that the explanation at once presents itself that this appearance arises from the fact that the deposits are partly a filling-in of interstitial spaces, and partly a replacement of thin sheets of country-rock, the differing composition of the bands resulting rather from the necessary variation in the process of deposition than from essential differences in the ore-bearing solutions. Were one to examine there only a large body of rich ore, and neglect to examine the adjoining poorer deposits, and to study the structural conditions of the region, one might be led to adopt some of the complicated explanations set forth in books on ore-deposits, such as successive reopenings of the vein, to account for the conditions found, instead of the simple one given above.

*Crushed zones.*—Cases occur where the systems of rock-fracture intersect each other, and under suitable conditions considerable portions of the country-rock included between such intersecting fractures may be broken up or crushed to such an extent as to admit a relatively free passage of percolating waters. Where such waters are mineral-bearing, the interstices between the fragments will offer spaces for the precipitation of their contents, or where the rock is readily soluble the fragments themselves may be replaced by vein-material.

Where three or more nearly vertical fracture-planes intersect each other near the same point, the prismatic body of rock included between these intersections may be so crushed and broken as, in a district rich in mineral-bearing solutions, to give rise to what are generally known as chimney deposits. Where the fracture-planes are merely joints along which there has been but little movement, and no clay selvages have consequently been formed, the ore-solutions will eat out into the rock in such a way that the ore-chimney may appear to have a rounded instead of an angular horizontal section, and the fracture-planes themselves may have become, by the decomposition of the adjoining country-rock, so obscured as to be with difficulty traced in the immediate vicinity of the ore-body.

*Repeated movements along fissure-planes.*—It is a well-recognised

*Structural Generalisations—continued.*

fact of structural geology that in successive dynamic movements in the same region there will be a tendency for fractures to follow already determined planes of fracture. Furthermore, it appears that the faulting of a rock-mass is not necessarily a geologically instantaneous movement, but that the displacement may continue for some time after the first fracture has been determined, probably dying out very gradually. Some such continued movement seems necessary to give time for the reduction by the action of water of the attrition material to the clayey condition in which it is often found. We may expect, therefore, to find evidence in large fissures of repeated movements.

Cross-fractures, and even apparent displacement of one fracture by another, may be produced by one and the same strain. Hence, in studying a system of fissures, one must not too hastily conclude that each direction of fracture means a distinct movement, or even that displacement of one fissure by another necessarily proves that the latter was produced by a distinct and later movement; to be sure of this, some of the other evidences of movement must be found.

Some very interesting facts in connection with two adjacent properties in Boulder Co., Colorado, are worthy of notice. The vein A runs first in porphyry, then in contact between porphyry and granite, and sometimes wholly in granite. The vein stone is a hard flinty white quartz. The gold is free and often very coarse; rarely accompanied by pyrite and chalcopyrite, increasing on entering the granite, when blende and galena also occur, but as tellurium-minerals.

The vein B is a bluish quartz, with chalcedony and finely disseminated pyrites. The value is in metallic gold, petzite, and sylvanite. While most of the metallic gold was deposited as native gold, a certain portion has evidently been rendered free by the partial decomposition of the tellurium-minerals. The richest ore usually occurs in two narrow seams or streaks, often only 1 ft., but at times as much as 10 ft. apart; the intervening space is more or less mineralised country-rock. The miners working as lessees on this vein consider it richest in the schistose rock, and poorest when it is in the porphyry, on its course through the dyke. Though the openings on the vein, in the dyke, are limited, this opinion appears to be correct.

So distinct are the characteristics of these veins, that the crossing of B through A is plainly marked, and confirms the opinion that the gold-mines of the country belong to at least two distinct periods of vein-formation.

That the ores from B (the tellurium-vein) are of lower grade where the vein passes through the porphyry dyke than elsewhere may be due to the formation of the A vein first. This vein probably drained the dyke of much of its disseminated mineral values. B doubtless received its mineral through the schistose or gneissic



*Structural Generalisations—continued.*

rocks, and is consequently richer where enclosed in those rocks than in the dyke.

Prospectors, as a rule, look for richer or larger bodies of ore where veins unite or cross each other. In this property we have two interesting occurrences of this kind. The A veins unite at a point 100 ft. below the surface. These are similar veins of the same age. The result is seen in larger and richer ore-bodies mined in the stopes adjacent to the junction of the veins. In the other case, the crossing of the B (tellurium) vein through the A veins, which was the passing of a later through earlier veins, produced no local enlargement or enrichment of the ore-bodies. It may be inferred with probability as a general rule, subject of course to local exceptions, that for the production, by the junction of two veins, of ore-bodies larger or richer than are characteristic of either vein separately, the two veins should be of contemporaneous origin.

Perhaps this last proposition may be both confirmed and explained by restricting its application to such cases of enrichment as result from the simple enlargement of the space available for deposition, and the consequent diminution of the speed of percolating currents—both of which conditions are observed to produce similar effects in veins which vary in dip or width but are not intersected by other veins. Practical miners look for the larger ore-bodies in the flat places and the wide places of the vein; and the pinches, though they do now and then compensate by special richness for their contracted size, are usually as “lean” as they are thin.

The theory of the formation of ore-deposits by replacement, as opposed to that by the filling of pre-existing cavities, may be applied to deposits in rocks which are not so readily soluble as limestone, in which cases the percolating solutions would have first attacked the relatively more soluble among their constituents. Very many so-called fissure-veins in crystalline rocks are formed by percolating water circulating along joints, shrinkage-cracks, fault-planes, or zones of crushed rock, which have filled the interstitial spaces and replaced the materials of the adjoining country-rocks to a greater or lesser extent by the materials they held in solution, but are not the filling of any considerable open cavities. The comb-structure of veins, on which the early geologists founded their theory that a vein was necessarily the filling of a pre-existing open cavity, is of comparatively rare occurrence.

Cracks or fissures must undoubtedly have existed, which determined the concentration of mineral solution along their course; but whether such cracks were to any great extent fault-planes, whose movement might have left large open spaces between the irregularities of their walls, seems questionable. In Leadville one of the most noticeable facts is that the fault-planes, which may be supposed to reach to great depths, have been found barren of ore except by secondary infiltration from surface-waters, or as

*Structural Generalisations—continued.*

attrition-material from pre-existing deposits, when the fault-line cuts across such deposits.

The idea that a fissure vein necessarily extends to an indefinite depth is another popular error, and not founded on good geological reasoning. Whatever the nature of the fissure along which the deposit has taken place, whether fault-plane, joint, or shrinkage-crack, there must be some mutual relation between its horizontal and its vertical dimensions. In other words, the study of structural geology shows that the length of such a fissure or crack must bear some proportional relation to its extent in depth, and the probability is that the latter must be less than the former.

The present tendency of the results reached by careful and well-authenticated determinations of the origin and manner of formation of ore-deposits is in favour of a continually increasing applicability of the following conditions:—

That they are deposited from solutions made by percolating waters.

That the deposition takes place very rarely in actually open cavities, but most frequently by a metasomatic interchange, or by replacement of the more soluble or more accessible portions of a rock or members of a rock-series.

That these solutions do not necessarily come directly upward, but simply follow the easiest channels of approach.

That these materials are not immediately derived from sources at some unknown depth, but from neighbouring bodies of rock within limited and conceivable distances.

That where, as is so often the case, ore-deposits are associated with, or in the vicinity of, bodies of eruptive rock, especially the older intrusive rocks, there is a reasonable probability that their materials have been derived from these rocks.

If the solutions came from the country-rock, at or above the level of the ore-deposit, it is most likely that the hanging-wall will be more or less obliterated, and the foot-wall relatively distinct. This follows from two considerations: first, because the rock of the hanging-wall is in such a case the main source of the water-supply for the fissure, the natural effect of gravity (apart from special water-channels) being to carry the waters of the foot-wall away from the vein, and to some other vein below it; and secondly, because the disintegrated rock of the hanging-wall would naturally deposit debris on the foot-wall, protecting it from disintegration, and thus preserving its definite form. The only "boundary" of such a vein would be a commercial one, viz. the line at which the ore ceased to pay.



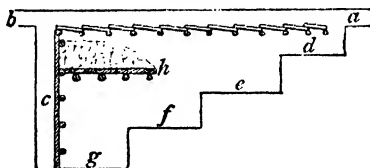
*Veins—continued.*

ing which forms the roof of the adit, and at the same time the floor of the chamber being excavated; *f*, a heap of ore broken down from overhead ready for running out of the adit; *g*, that portion of the mineral which has no value, and which accumulates under the feet of the miners as their work progresses; *h*, a substantial wall forming one side of the shaft *c*, sometimes built of the larger pieces of rock broken down from *i*, but more often timbered; *i*, the unworked portion of the vein; *k*, space in which the miners wield their tools.

The advantages of this system are that less timber is needed, and the ore is more easily brought to bank; its disadvantages are that the miner has to reach upwards to his work, and that some ore must necessarily get mixed with the rubbish *g* and be lost. It is by far the most widely adopted.

(*b*) *Underhand Mining when the vein does not exceed 2 fathoms thick.*—From the main adit *a b*, Fig. 40, a shaft *c* is sunk on the vein.

Fig. 40.



Underhand Mining.

Then, commencing at *d*, miners standing on the ore in the vein excavate it in a series of steps *d e f g*, the ore having to be raised by windlass or other contrivance through openings in the floor timbers of the adit *a b*, whilst the rubbish is thrown back on strong timber shelves *b* built against the wall of the shaft *c*.

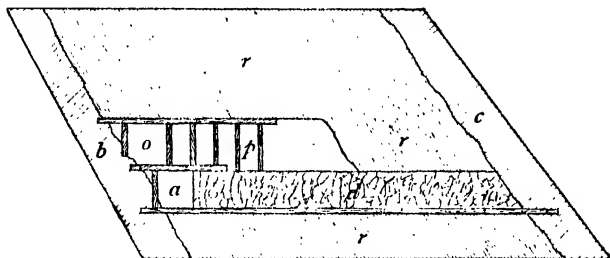
The advantages of this system are that the miner has easier access to the ore, and can apply more power, whilst the loss of ore is less. The disadvantages are extra cost for timbering and transporting ore to bank, and increasing difficulties in ventilation and removal of water.

(*c*) *Crosswork on veins over 2 fathoms thick.*—With very thick veins it is necessary to modify either of the systems before mentioned, so as to deal with the width of the vein in successive sections. This is illustrated in Figs. 41, 42. A main gangway *a* is first driven along either wall *b c* of the vein *r*, and substantially timbered. From it a series of breasts or crosscuts *d e f g h i* are driven at right angles through the vein till they reach the opposite wall *c*. These breasts are 1 fathom high and 1–2 fathoms wide, and are so worked as always to have firm ground on both sides of them, either solid ore as at *k l m n*, or rubbish stowed back in a former breast as at *d*.

*Veins*—continued.

As one level is worked out, new gangways, as at *o*, are driven overhead, and the crosscutting is repeated, with timbering *p* where necessary, and always providing that no two breasts in the same vertical line shall be worked simultaneously.

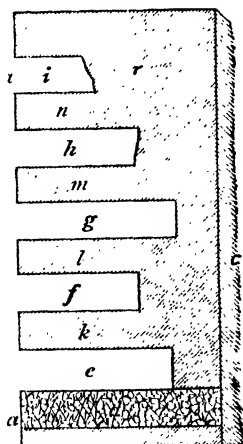
Fig. 41.



Crosswork on Thick Veins.

(*d*) A modification of the ordinary method of timbering in mines, which has long been in general use on the Pacific Coast, is shown

Fig. 42.



Crosswork on Thick Veins.

in Figs. 43, 44. Sawn timber is used throughout, the uprights and cross-pieces are 10 in.  $\times$  10 in., and stand 4 ft. 6 in. apart;

*Veins*—continued.

along the course of the drive, the cross-pieces are 5 ft. long, and the height of the main drives and sill floor sets is 7 ft. 2 in. clear.

Fig. 43.

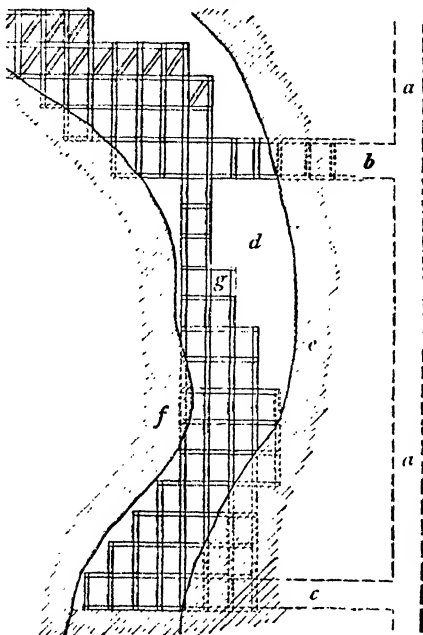
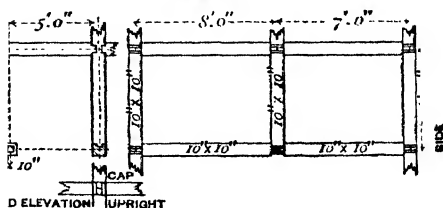


Fig. 44.



Square or Nevada Timbering.

In blocking out the stopes, the uprights are 6 ft. 2 in., just 1 ft. shorter than those in the main drives. The caps and struts are of

*Veins—continued.*

the same dimensions and timber as the sill floor. The planks used as staging are 9 in.  $\times$  2½ in.; they are moved from place to place as required, and upon them the men stand when working in the stopes and in the faces. A stope resembles a huge chamber fitted with scaffolding from floor to roof. The atmosphere is cool and pure, and there is no dust. Stage is added to stage, according as the stoping requires it, and ladders lead from one floor to the other; the accessibility to the faces is a great advantage. If, whilst driving, a patch of low-grade ore is met with, it can be enriched by taking a higher class from another face, and so on; any grade can be produced by means of this power of selection. Opinions have been expressed that this system of timbering is not secure, and that pressure from above would bring the whole structure down in ruins. But if signs of weakening in the timbers become apparent, the remedy is very simple. Four or more of the uprights are lined with planks, and waste material is shot in from above, and a strong support is at once formed; or if signs of crushing are noticed, it is possible to go into the stope, break down ore, and at once relieve the weight. The cost is said to be 30 per cent. less than in the usual system, the ventilation is unimpeded, and much timber is saved. This method is commonly known as the "Nevada" or "Square" system of timbering.

(e) Excellent examples of the contingencies arising in the course of long continued mining operations are afforded by the East and West Vulcan mines of the Penn Iron Mining Company, Michigan. The ore occurs here in immense bodies, lying between hard jasper-slates and soft clay slates; it is soft hematite, and varies in thickness from a few inches to over 100 ft. The earliest mining methods were of the crudest sort, but the gradual increase of depth and multiplication of difficulties have compelled successive improvements.

The first was the introduction of the Nevada system of timbering, which, as already described under (d), p. 278, consists in filling the space exhausted in the ore-body with a series of frame cubes. These cubes are constructed with white pine timber of excellent quality, 12 to 15 in. sq., framed into squares of 7 ft. from centre to centre. There is great value in this system of timbering as related to strength, facility in erecting, and its adaptability to all thicknesses of ore-deposits or variations in hanging and foot-walls. When the walls are tolerably firm and not easily softened by exposure to the moist atmosphere of the mine, it possesses great strength; but where the hanging-wall is of soft clay-slates, softening rapidly on exposure, this system with its large timbers affords only temporary support. When the crush begins, the upright posts lose their vertical position, and many of the timbers are reduced to splinters. Collars and cross-braces are sometimes used to arrest a squeeze; but a brief respite only is secured in this way. The flexure of a soft hanging-wall indicates the early crushing of timbers in the

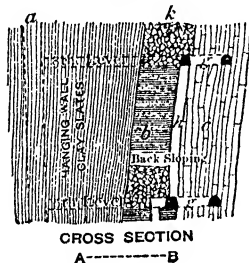
*Veins—continued.*

exhausted portion of the level. It becomes then a struggle on the part of the miner to remove as much as possible of the ore out of the creeping level before the final crush comes to close out all mining operations. It has thus been found that for certain qualities of mine-walls this elaborate system of timbering fulfils its office satisfactorily, but that under a softening hanging- or foot-wall it is not reliable for a sufficient time to afford opportunity for exhaustive mining in each level, or to protect ways to the adjoining level. The depth to which it can be safely carried depends on the firmness of the hanging- and foot-walls more than on the increased pressure from depth, although the latter is also an important factor.

The latest and modern method of "rock-filling" was compelled by the conditions, already described, in the West Vulcan mine. At the eighth level the ore is 600 ft. long and the average thickness about 25 ft. The shaft is 665 ft. deep to the ninth level. The timbering, mainly after the Nevada system, has been carried to the eighth level. Rock-filling is now being used in the ninth level.

Figs. 45-47, show the method of this filling. From the main shaft *a* a drift cuts the ore-body *b* and 25 ft. into the foot-wall *c* of

Fig. 46.



Rock-filling at West Vulcan.

firm jasper-slates. From this point *d* a rock-tunnel *e* is driven in the foot-wall *c* east to shaft *f*. Along this rock-tunnel *e* ports *g* are made at intervals of about 100 ft. into the ore-body *b*. From these ports the mining of the ore begins on the bottom of the ninth level.

The first cut of this ore is mined about 8-10 ft. high, and the spaces from which the ore has been removed are filled with rock. This rock-filling *h* follows the mining and affords absolute safety and inflexible support to the walls of the mine. The broken rock for filling is conveyed down the winzes *h*, and the ore through the shutes *i*, which are built up as fast as the filling is made upwards.



Fig. 45.

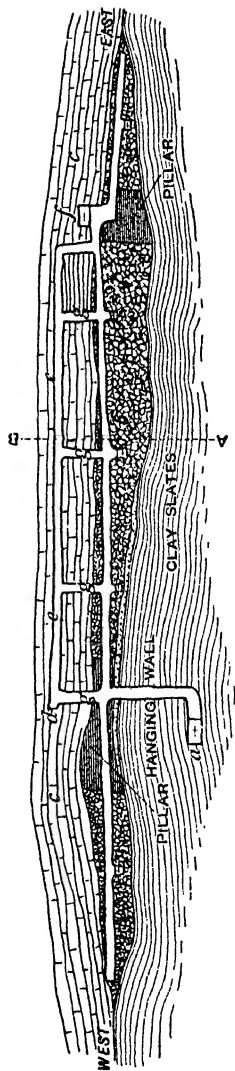
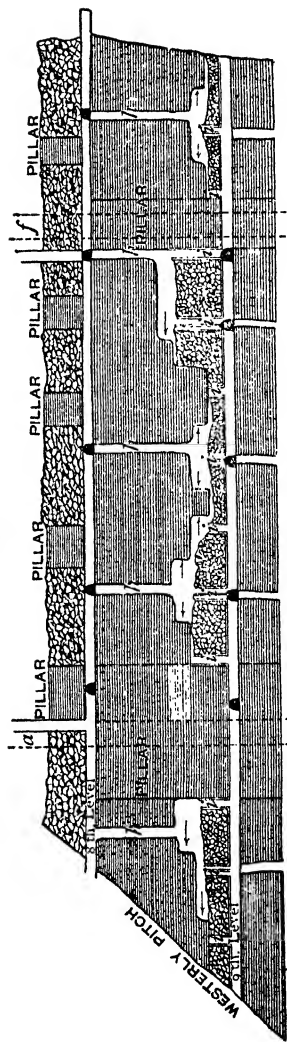


Fig. 47.



Rock-filling at West Vulcan.

*Veins—continued.*

It will thus be seen that the tunnel *e* in the foot-wall secures absolute safety to the mainways of each level; it is out of the crush range in any event. The winzes *h* are also ventilators, and greatly improve the sanitary conditions of the mine.

The ore-body *b* is under this system attacked by the miners on double face at each port *g*, from the main rock level or tunnel *e* in the foot-wall. The mining by sections upwards is simply a repetition of the first 8–10 ft., the rock filling following the mining work and occupying the spaces from which the ore has been removed as rapidly as room for the mining operations will permit. Some timbering will be required occasionally in this rock-filling, especially in sustaining the filling in upper levels, as it is approached from below in removing the last cut of ore.

This rock-filling system has not been adopted on the score of economy over the Nevada system of timbering, but has been compelled by the necessities of the case. Sufficient work has not been done to afford a reliable statement of the relative cost of the two systems. Nor would such a statement at any time form a permanent basis of comparison, because the forests of this region are being exhausted, with consequent effects on the market prices of timber, while the cost of breaking up and shooting waste rock into the mine fluctuates but little. The price paid for timber and timbering at West Vulcan in 1887 was 1s. 7½d. per ton of ore mined. The cost of rock-filling, with attendant consumption of timber per ton of ore mined, was 7d. a ton for rock-filling and 3d. a ton for timber used therewith. These estimates require verification by a few years of actual work. It may be pointed out that the rock-filling affords a permanent support, which is not liable to decay as is the timbering system, and will not require renewals during the progress of the mine-workings.

There are other important factors in connection with the general application of this system of rock-filling, e. g. the location of the shafts or slopes to the mines. The first planning of these slopes or skip-ways placed them in the ore-body, requiring large pillars of ore for their maintenance. Where the ore is of moderate thickness (12–15 ft.) this method is not so open to criticism; but when the ore-body is 20–100 ft. thick and rather soft, it has serious drawbacks in the great pillars of ore which must be set apart for this purpose, and in their tendency to crumble, especially in the event of a creep or crush, which follows in a greater or less degree in exhaustive mining. The use of skip-ways in the foot-walls, or the sinking of shafts in the hanging-walls, are matters of the greatest importance in assuring safe and economical mining. It has been shown that slopes or skip-ways in the ore-body are open to serious objections in large deposits of ore. It is quite possible to sink the slopes or skip-ways in the foot-wall, especially when this is firm. They could be driven in the foot-wall, and a sufficient distance under the plane of the ore, say 10–20 ft., so as to assure a perma-

*Veins—continued.*

nent rock tunnel under all conditions of creep or crush. This will have some exceptions, as where the ore-body is much flexed and pitching; but there are many deposits where a slope or skip-way could be driven in the foot-wall of an ore-deposit, and be readily made to conform to the flexures met, in ordinary cases, in these foot-walls. This would be costly at first, but it would ultimately be found to assure great safety, and permit exhaustive mining, since no pillars would be required for its protection.

West Vulcan mine exhibits an example of approaches by slope or skip-ways, partly in foot-wall slates, and a vertical shaft in the soft slates of the hanging-wall. The location of the main shaft in the hanging-wall was the result of several conditions bearing on the ultimate economy of mining its ore. It is near the siding of the railroad, affording a ready way for delivering the ore into railroad cars, and also for receiving coal by the same way for the boilers, and timber for the mine. This location also reduced largely the height of the pumping column, and the shaft was sunk in soft slates rapidly and cheaply. Aside from these special conditions, the locating of a shaft in the hanging-wall cannot be commended, as there is generally some shifting in the hanging-wall ground, endangering shaft and machinery.

It has been a matter of discussion whether the usual method of mining by beginning operations at or near the surface and working downwards, in the best plan. It is true that it affords a ready output of ore, and a quick return of money; but, unless permanent rock-ways are established, it involves increasing expenditure in the downward workings. It is submitted, that in deposits of ore of moderate thickness, a slope could be cut in the ore to the bottom of the deposit, and workings commenced there, entirely exhausting the ore in the progress of the working upwards. The exhausted spaces below would afford a ready place for mining refuse, and could, if necessary, be supplemented with additional rock-filling. Even should the hanging-wall swell or buckle, no serious injury could result, as such a crush would be arrested at each level. (J. Fulton.)

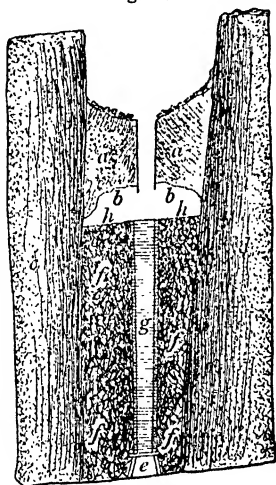
The objections to the rock-filling system are the amount of dead work entailed, and the inconveniences and destruction of timbering owing to the ground sinking unevenly under foot.

(*f*) The system of mining in use at the Iron River mine, Menominee region, is extremely well adapted to ores hard enough to stand over the width of the vein. A section across a stope (Fig. 48) shows the method of work. The ore *a* is taken down in an overhand stope *b* running the width of the vein from the hanging-wall *c* to the foot-wall *d* for any desirable length, and for a height of say 12 ft. A timber-drift *e* is then built along the floor of the stope, and the balance *f* of the stope is packed with waste sent down from the surface through winzes previously sunk or upraised at intervals of about 50 ft. in the length of the stope. A "mill" or "chute" *g*

*Veins—continued.*

is carried up every 50 ft. along the level to run the ore down; it is about 4 ft. sq. inside, and is built of round, rough hardwood sticks. The spaces between the sticks when they do not fit closely are filled with pieces of plank, and the inside of the "mill" is lined with hardwood planks spiked on to the side timbers. These planks are easily replaced when worn. The packing is levelled over as close to the backs of the stope as is convenient for working, and is planked  $\frac{1}{2}$  over, to keep the ore from mixing with the filling. The "mill" is

Fig. 48.



Working on Hard Vein at Iron River.

carried up before the filling as high as this is to go; and when the filling is levelled off, a few large sticks are laid across the mill, leaving intervals large enough to throw the ore down, but so narrow as to prevent the falling in of a man or a block of ore that would choke up the outlet from the mill. This method is extremely satisfactory where the ore is strong enough to stand without timbering across the vein. It requires no timber, except for the level and the mills, and a few planks, while permitting the extraction of nearly all the ore. The cost of filling at Iron River was only  $6\frac{1}{2}d.$  a ton on the ore got out, but on the average this figure would be much exceeded.

(g) For working in large soft ore bodies, Rothwell thinks it would be found in every way advantageous to work the vein out from the top downwards. He would drive the main levels *a* in

*Veins*—continued.

the vein *b* (Figs. 49–50), and most conveniently on the footwall *c*, *d* being the hanging-wall. As the ground is undisturbed, it should be feasible to keep open a level the width of an 8-ft. set, no matter how soft the ore, thus avoiding much dead work. At suitable

Fig. 49.

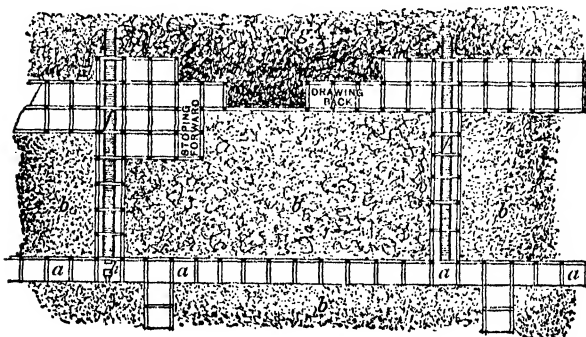
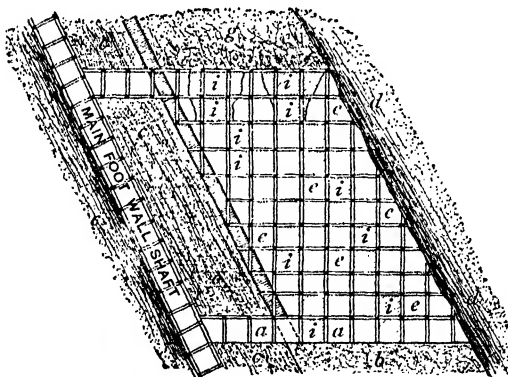


Fig. 50.



Working Downwards on Soft Ore Bodies.

intervals the vein would be cross-cut *e*, and stoped out the width of one set, up from one level to the next above. However soft the ore it should be possible, even with rather light timber, to hold a stope only 8-9 ft. wide running across the vein in the solid well-

*Veins*—continued.

drained ore. This will take the place of winzes and cross-drifts at much less cost, and will serve as a pocket or chute *f* to hold the ore, which can be drawn thence into the cars *h* below; or the mill or chute *f*, through which the ore is sent down, can be built say 3½ by 4 ft. in the clear, of round hardwood sticks lined with hardwood plank. By a little care in packing round it, this can probably be held in the filling *g* as a waste mill, through which filling may be sent down from above; or the mill can be cut in the foot-wall. When the cross-stope reaches the upper worked-out ground, longitudinal stopes *i*, one or two sets in height and one set in width, are driven to half the distance between the cross-stopes, leaving between them intervals or pillars two sets wide or more if the ground permits. These longitudinal stopes are timbered lightly, having to stand but a very short time, and being in the solid undisturbed ore, with the filling from above resting on each side of them on solid ore. When the mid-distance between the cross-stopes is reached the back-stoping commences by taking out the ore on each side of the stope *i* to the width of a set, or half the pillar left between the longitudinal stopes *i* supporting the "gob" roof while doing so, and laying lagging poles or slabs across the floor of the stope as the work proceeds. Any waste rock or material available or desirable may be thrown back in the packing, and when a space the area of one or two sets is worked out on each side of the last sets of the longitudinal stope *i*, the temporary timbering is drawn, and the "gob" roof, with the lagging previously laid under it, is allowed to drop on the bottom of the stope lagged to receive it. Light poles, and even brushwood, will serve for thus keeping the ore from mixing with the waste. It will probably be found possible, as well as advantageous in many cases, to drive these longitudinal stopes *i* two sets high, and draw back the upper one a little in advance of the lower, and as they can be driven out at any point in the cross-stope, a whole horizontal slice or section of the ore-body, no matter what its thickness, can be opened out, say two sets in height, at the same time.

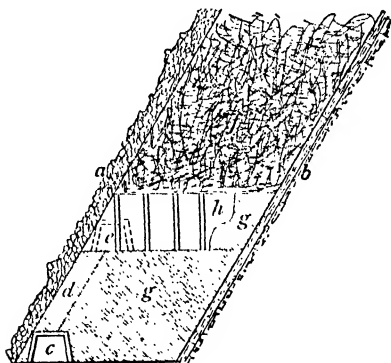
The advantages claimed for this system are: (1) that all the work is simply stoping; (2) all levels and stopes that have to be timbered are in solid, undisturbed ore, and being only one "set" in width, are easily held, and require but light timber, while much of this is drawn and saved in letting the roof down; when the stope comes up to the filling, this has only to be supported over one set of timber, while it rests on the solid ore on each side; (3) the filling follows the ore down, and as long as this occurs, the cave on the surface can be constantly filled from "borrow pits" much cheaper than by sending the filling below; (4) it is possible to obtain practically all the ore in the vein, and to get it free from mixture with waste; (5) caves or crushes are impossible; (6) more ore can be extracted from a given amount of ground in a given time.

(*h*) Another example of working in soft ore bodies is that at

## Veins—continued.

**Low Moor, Virginia.** The ore is generally soft, and all drifts require close timbering. The hanging-wall *a* (Fig. 51) is a band of broken flint and clay, and the footwall *b* is sandstone. Main levels *c* are driven in the vein along its strike, 60-80 ft. apart vertically, starting from the surface on the side of the hill or from a hoisting shaft in the valley.

They are usually on the flint wall, whether it be the foot or the hanging, because the flint is a better guide in following the vein. These levels are driven along the vein to such a distance from the hoisting-shaft as may be required to reach all the ore which it is intended to raise through that shaft—in some instances over half a



Working on Soft Ore Bodies.

mile. While the main levels are being driven, the pillar between two levels is usually left untouched, except by up-raises connecting the two levels every 400-600 ft. for ventilation. When the levels are completed, the portions of two levels farthest from the hoisting-shafts are connected with up-raises *d*, 60-75 ft. apart, two or three up-raises are joined by air-drifts *e*, and the ground is ready for stoping. The timber in the air-drifts is recovered in stoping. The stopes are 12-15 ft. high, each pillar between two main levels making 4-6 stopes. As soon as a stope is worked out for 40-60 ft. along the vein, a floor is laid, consisting of sills covered with refuse timber or slabs, and the props are shot down. The waste material *f* from above packs solidly upon this floor, and in a short time the next lower stope can be worked, using the floor previously laid as a roof to hold the waste material from the ore. A stope 40-60 ft. long, measured along the vein, is begun in the drifts, by first mining the ore *g* above the drift-timbers till the floor of the next

*Veins—continued.*

stope above is reached, and setting props. The face of the ore for the length of the stope is then mined back to the opposite wall, as shown at *h*. The ore is dumped into the chutes *d*, drawn from them into cars on the main levels *c*, and hauled by mules to the surface or to the hoisting-shaft.

When the vein is 12 ft. or less in thickness, so that a single prop will reach from wall to wall, the method is somewhat modified. A stope-drift is driven a short distance above the main level, parallel with it, and connected with it by chutes at intervals of about 50 ft. The ore is then stoped from this drift to the next upper main level, props being placed from wall to wall. These props are eventually shot down, and the waste material is caught by a horizontal floor, which will serve as a roof for the next lower stope, as before. In this way the timber for a number of floors is saved, but the modification is only of advantage when the vein is narrow enough to permit a single prop to reach from wall to wall, and where, moreover, the hanging wall is fairly good. In this way all the ore is mined, no filling is required, and the work is comparatively safe. In some instances, means must be taken to exclude surface water from the breaks which run up to daylight when the country rock sinks to fill cavities.

(i) *Stripping*.—This term is applied to what is really simple quarrying adapted to the exploitation of a vein. It has been rendered possible by modern improvements in mining machinery and appliances, which allow of much more complete preliminary determination of the quality and extent of underground deposits, and much less costly blasting operations. The advantages of stripping are that the work is conducted in the open day, and that there is less risk of unremunerative dead work on the one hand and of overlooking ore on the other.

At the Peters mine, Ringwood, New Jersey, where the limit of profitable mining by the old method has been reached, it is intended to remove the ore floors and pillars by stripping. While the vein stands nearly vertical, the ore shoots overlies each other at an angle of  $35^{\circ}$  and some 10–30 ft. apart. It is proposed to take advantage of this, and pile up the waste on the end wall of the lowest shoot as rapidly as the wall is uncovered by removal of ore. This back filling will make the mine safer, and will save much excavation by allowing the slopes to be considerably steeper than if the pit were to be left open permanently.

At the Bertha zinc mines, in Virginia, zinc carbonates are found to the extent of about 8000 tons per acre, underlying some 80 ft. of earth, so that 30 cub. yd. of earth have to be removed for every ton of ore mined.

In the case of the Dannemora mine, Sweden, stripping has been successfully carried to a depth of about 500 ft., and at the Fahlun copper mines to even greater depths.



*Beds.*

(a) *Longwall*.—The “longwall” method, which closely resembles the overhead system already described, is applicable to nearly horizontal thin beds which furnish sufficient waste for filling. The

Fig. 52.

□ *b*

Fig. 53.

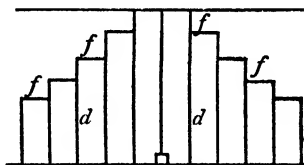
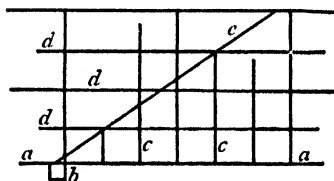
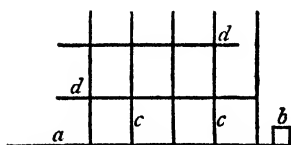


Fig. 55.



Longwall and Pillar and Stall Working.

main tunnel *a*, Figs. 52, 53, is built high enough to accommodate the trucks for transporting the mineral to the hoisting shaft *b*, and is run at the lowest part of the bed so as to form a natural drainage for the mine water. From it drifts are run into the mineral, either diagonally as at *c*, or transversely as at *d*, and connected by parallel levels *e*. The direction of the drifts is governed by the rate of dip of the bed, the object being to secure a suitable incline for the trucks which carry out the mineral. The workings are connected all round by cross-cuts as at *f*, to complete the circulation of air for ventilation.

(b) *Pillar and Stall*.—This system is adopted where the beds are thicker and do not afford sufficient waste for filling, so that pillars of mineral have to be left standing as a support for the roof. The main tunnel *a*, Figs. 54, 55, is run as before from the shaft *b*, and from it are run drifts *c* at intervals, and crossing these again, levels *d* parallel with *a*, and occasionally diagonal drifts *e*. The bed is thus divided into regular blocks, portions of which, varying in size, are left to form the pillars that support the roof, these being finally withdrawn as far as safety will allow.

*Beds—continued.*

In seams having a rate of dip of 40-60° it is the custom to drive the stalls square off from the gangway, up the "rise" of the seam, and have the coal to run down the shute into the tram at the bottom of it; with this rate of dip the shute does not require planking at the side or bottom to make the coal run, and by keeping the shute full, except 3-4 ft. working room at the breast, there is very little coal lost by pulverising in its descent down the shute, as by that method it descends by slow settling in proportion as it is allowed to run into the trams at the bottom.

In seams of 30-40° rate of dip, the miners are compelled to plank the sides of the shute to some extent, in order to enable the coal to slide down without assistance. In seams of 25-30° the coal will not descend in the shute unless the sides are partly planked, and the bottom covered with sheet iron. In working seams having a dip of 10° or under, the stalls are driven diagonally to the direction of the gangway, unless the rate of dip is less than 4°.

The trams or mine cars used in Europe are, in nearly every case, smaller than the American; the reason for making them so, in most cases, is an effort to reduce the enormous first cost of the deep shafts, by having a small shaft area, thus leaving but a small space for the mine cars or cages and pumpway; the small mine cars also suit the large number of boys employed in European mines.

## COAL SEAMS.

*Calculating Contents.*

A rough and ready way of calculating the available contents of coal in a given area of seam is to take a basis of 1 acre 1 in. thick = 100 tons. A more correct way is to ascertain the sp. gr. and multiply by that. In round figures, the sp. gr. taken to two places of decimals will represent the weight of 1 acre 1 in. thick if the decimal point be struck out; thus sp. gr. 1.10 = about 110 tons per acre 1 in. thick.

Table 131.—*Coal Seams.* Sp. gr.; weight per acre, per cub. ft., per cub. yd., and per cub. ft. when broken.

Sp. gr.	Natural Weight per acre 1 in. thick.	Natural Weight per cub. ft.	Natural Weight per cub. yd.	Broken Weight per cub. ft.	
				Large.	Small.
	tons	lb.	tons	lb.	lb.
1.10	111½	68½	.829	42½	37
1.15	116½	72	.867	44½	38½
1.20	121½	75	.904	46½	40½
1.25	126½	78	.941	48½	42
1.30	131½	81½	.978	50½	43½
1.35	136½	84½	1.016	52½	45½
1.40	141½	87½	1.054	54½	47½
1.45	146½	90½	1.091	56	49
1.50	152	93½	1.129	58	50½
1.55	156½	96½	1.167	60	52½
1.60	162	100	1.200	62	54

*Coal Heaps.*—To estimate contents of coal heaps, measure the cubic space occupied and multiply the result, stated in cub. yd., by 6; the product = contents in tons.

Table 132.—*Weight of Coal under 1 acre of land, at 19 cwt. per cub. yd., or 78½ lb. per cub. ft., approximate, and assuming seam to be level.*

ft. in.	tons.	ft. in.	tons.	ft. in.	tons.
0 1	127	3 5	5,212	6 9	10,260
0 2	254	3 6	5,346	6 10	10,390
0 3	381	3 7	5,468	6 11	10,520
0 4	508	3 8	5,596	7 0	10,650
0 5	635	3 9	5,724	7 1	10,780
0 6	762	3 10	5,852	7 2	10,910
0 7	889	3 11	5,980	7 3	11,040
0 8	1,016	4 0	6,096	7 4	11,170
0 9	1,143	4 1	6,124	7 5	11,300
0 10	1,270	4 2	6,252	7 6	11,430
0 11	1,397	4 3	6,380	7 7	11,560
1 0	1,524	4 4	6,508	7 8	11,690
1 1	1,651	4 5	6,636	7 9	11,820
1 2	1,778	4 6	6,764	7 10	11,950
1 3	1,905	4 7	6,892	7 11	12,080
1 4	2,032	4 8	7,020	8 0	12,210
1 5	2,159	4 9	7,148	8 1	12,340
1 6	2,296	4 10	7,276	8 2	12,470
1 7	2,417	4 11	7,404	8 3	12,600
1 8	2,534	5 0	7,532	8 4	12,730
1 9	2,661	5 1	7,660	8 5	12,860
1 10	2,790	5 2	7,788	8 6	12,990
1 11	2,917	5 3	7,916	8 7	13,120
2 0	3,048	5 4	8,046	8 8	13,250
2 1	3,176	5 5	8,180	8 9	13,380
2 2	3,304	5 6	8,310	8 10	13,510
2 3	3,432	5 7	8,440	8 11	13,640
2 4	3,560	5 8	8,570	9 0	13,770
2 5	3,687	5 9	8,700	9 1	13,900
2 6	3,815	5 10	8,830	9 2	14,030
2 7	3,943	5 11	8,960	9 3	14,160
2 8	4,070	6 0	9,090	9 4	14,290
2 9	4,198	6 1	9,220	9 5	14,420
2 10	4,326	6 2	9,350	9 6	14,550
2 11	4,454	6 3	9,480	9 7	14,680
3 0	4,576	6 4	9,610	9 8	14,810
3 1	4,700	6 5	9,740	9 9	14,940
3 2	4,828	6 6	9,870	9 10	15,070
3 3	4,956	6 7	10,000	9 11	15,200
3 4	5,084	6 8	10,130	10 0	15,330

Table 133.—*Area of Coal Seams when inclined.*

Amount of Dip.			Coal Contents.	Amount of Dip.			Coal Contents.
1 in	deg.	in. per yd.	sq. yd. per acre.	1 in	deg.	in. per yd.	sq. yd. per acre.
57½	1	½	4,841	1·66	31	21½	5,646½
2¾	2	1¼	4,843	1·60	32	22½	5,707½
19	3	1¾	4,846½	1·54	33	23½	5,771
14½	4	2½	4,852	1·48	34	24½	5,838
11½	5	3	4,858½	1·42	35	25½	5,908½
9¾	6	3¾	4,866½	1·37	36	26	5,982½
8	7	4½	4,876	1·32	37	27	6,060½
7	8	5	4,887½	1·28	38	28	6,142
6½	9	5¾	4,900	1·23	39	29	6,228
5½	10	6½	4,914½	1·19	40	30½	6,318½
5	11	7	4,930½	1·15	41	31½	6,413
4¾	12	7½	4,948	1·11	42	32½	6,513
4½	13	8½	4,967	1·07	43	33½	6,618
4	14	9	4,988	1·03	44	34½	6,728½
3¾	15	9½	5,011	1·00	45	36	6,844½
3½	16	10½	5,035	·96	46	37½	6,967½
3½	17	11	5,061	·93	47	38½	7,096½
3½	18	11½	5,089	·90	48	40	7,233½
2·90	19	12½	5,119	·87	49	41½	7,377½
2·74	20	13	5,151	·84	50	43	7,529½
2·60	21	13¾	5,184	·81	51	44½	7,691
2·47	22	14½	5,220	·77	52	46	7,861½
2·35	23	15½	5,258	·73	53	47½	8,040
2·24	24	16	5,298	·70	54	49½	8,217½
2·14	25	16¾	5,340	·67	55	51½	8,419½
2·05	26	17½	5,385	·65	56	53½	8,639½
1·96	27	18½	5,432	·63	57	55½	8,873
1·88	28	19	5,481½	·62	58	57½	9,139
1·80	29	20	5,534	·60	59	60	9,430
1·73	30	20½	5,589	·58	60	62½	9,759

The cubic contents in yd. may be deduced from this table by multiplying the figure in the fourth column by the thickness in yd. or fractions of a yd.

*Ex. 1.* A seam 1 ft. 6 in. thick lying at an inclination of 16½ in. per yd. will contain 5340 sq. yd.  $\times$  .5 yd. = 2670 cub. yd.

*Ex. 2.* A seam 1 fathom thick lying at 39° will contain 6228 sq. yd.  $\times$  2 yd. = 12456 cub. yd.

## MINERALS.

## HARDNESS. (Dana.)

The comparative hardness of minerals is easily ascertained, and should be the first character attended to by the student in examining a specimen. It is only necessary to draw a file across the specimen, or to make trials of scratching one with another. As standards of comparison the following minerals have been selected, increasing gradually in hardness from talc, which is very soft and easily cut with a knife, to the diamond. This table, called the scale of hardness, is as follows:—

1, talc, common foliated variety; 2, rock salt; 3, calcite, transparent variety; 4, fluorite, crystallised variety; 5, apatite, transparent crystal; 6, orthoclase, cleavable variety; 7, quartz, transparent variety; 8, topaz, transparent crystal; 9, sapphire, cleavable variety; 10, diamond.

If, on drawing a file across a mineral, it is impressed as easily as fluorite, the hardness is said to be 4; if as easily as orthoclase, the hardness is said to be 6; if more easily than orthoclase, but with more difficulty than apatite, its hardness is described as  $5\frac{1}{2}$  or 5.5.

The file should be run across the mineral three or four times, and care should be taken to make the trial on angles equally blunt, and on parts of the specimen not altered by exposure. Trials should also be made by scratching the specimen under examination with the minerals in the above scale, since sometimes, owing to a loose aggregation of particles, the file wears down the specimen rapidly, although the particles are very hard.

In crystals the hardness is sometimes appreciably different in degree in the direction of different axes. In crystals of mica the hardness is less on the basal plane of the prism, that is, on the cleavage surface, than it is on the sides of the prism. On the contrary, the termination of a crystal of cyanite is harder than the lateral planes. The degree of hardness in different directions may be obtained with great accuracy by means of an instrument called a sclerometer.

## TENACITY. (Dana.)

The following rather indefinite terms are used with reference to the qualities of tenacity, malleability, and flexibility in minerals:—

1. *Brittle*.—When a mineral breaks easily, or when parts of the mineral separate in powder on attempting to cut it.

*Tenacity*—continued.

2. *Malleable*.—When slices may be cut off, and these slices will flatten out under the hammer, as in native gold, silver, copper.

3. *Sectile*.—When thin slices may be cut off with a knife. All malleable minerals are sectile. Argentite and cerargyrite are examples of sectile ores of silver. The former cuts nearly like lead, and the latter nearly like wax, which it resembles. Minerals are imperfectly sectile when the pieces cut off pulverise easily under a hammer, or barely hold together, as selenite.

4. *Flexible*.—When the mineral will bend, and remain bent after the bending force is removed. Example, talc.

5. *Elastic*.—When, after being bent, it will spring back to its original position. Example, mica.

A liquid is said to be *viscous* when on pouring it the drops lengthen and appear ropy.

#### DIAPHANEITY. (Dana.)

Diaphaneity is the property which many objects possess of transmitting light; or, in other words, of permitting more or less light to pass through them. This property is often called transparency, but transparency is properly one of the degrees of diaphaneity. The following terms are used to express the different degrees of this property:—

*Transparent*—when the outlines of objects, viewed through the mineral, are distinct. Example, glass, crystals of quartz.

*Subtransparent*, or *semitransparent*—when objects are seen but their outlines are indistinct.

*Translucent*—when light is transmitted, but objects are not seen. Loaf-sugar is a good example; also Carrara marble.

*Subtranslucent*—when merely the edges transmit light faintly.

When no light is transmitted the mineral is described as *opaque*.

#### LUSTRE. (Dana.)

The lustre of minerals depends on the nature of their surfaces, which causes more or less light to be reflected. There are different degrees of intensity of lustre, and also different kinds of lustre.

a. The kinds of lustre are six, and are named from some familiar object or class of objects.

1. *Metallic*—the usual lustre of metals. Imperfect metallic lustre is expressed by the term submetallic.

2. *Vitreous*—the lustre of broken glass. An imperfect vitreous lustre is termed subvitreous. Both the vitreous and subvitreous lustres are common. Quartz possesses the former in an eminent degree; calcite often the latter. This kind of lustre may be exhibited by minerals of any colour.

*Lustre*—continued.

3. *Resinous*—lustre of the yellow resins. Example, some opal, zinc blende.

4. *Pearly*—like pearl. Example, talc, native magnesia, stilbite, &c. When united with submetallic lustre the term metallic-pearly is applied.

5. *Greasy*—looking as if smeared with oil. Example, clæolite, some quartz.

6. *Silky*—like silk; it is the result of a fibrous structure. Example, fibrous calcite, fibrous gypsum, and many fibrous minerals, more especially those which in other forms have a pearly lustre.

7. *Adamantine*—the lustre of the diamond. When sub-metallic, it is termed metallic adamantine. Example, some varieties of white lead-ore or cerussite.

b. The degrees of intensity are denominated as follows:—

1. *Splendent*—when the surface reflects light with great brilliancy and gives well-defined images. Example, crystals of hematite, cassiterite, some specimens of quartz and pyrite.

2. *Shining*—when an image is produced, but not a well-defined image. Example, calcite, celestite.

3. *Glistening*—when there is a general reflection from the surface, but no image. Example, talc.

4. *Glimmering*—when the reflection is very imperfect, and apparently from points scattered over the surface. Example, flint, chalcedony.

A mineral is said to be *dull* when there is a total absence of lustre. Example, chalk.

### COLOUR. (Dana.)

1. *Kinds of Colour*.—In distinguishing minerals, both the external colour and the colour of a surface that has been rubbed or scratched, are observed. The latter is called the streak, and the powder abraded, the streak-powder.

The colours are either metallic or unmetallic.

The metallic are named after some familiar metal, as copper-red, bronze-yellow, brass-yellow, gold-yellow, steel-grey, lead-grey, iron-grey.

The unmetallic colours used in characterising minerals are various shades of white, grey, black, blue, green, yellow, red, and brown.

There are thus snow-white, reddish-white, greenish-white, milk-white, yellowish-white.

Bluish-grey, smoke-grey, greenish-grey, pearl-grey, ash-grey.

Velvet-black, greenish-black, bluish-black, greyish-black.

Azure-blue, violet-blue, sky-blue, indigo-blue.

Emerald-green, olive-green, oil-green, grass-green, apple-green, blackish-green, pistachio-green (yellowish).



*Colour*—continued.

Sulphur-yellow, straw-yellow, wax-yellow, ochre-yellow, honey-yellow, orange-yellow.

Scarlet-red, blood-red, flesh-red, brick-red, hyacinth-red, rose-red, cherry-red.

Hair-brown, reddish-brown, chestnut-brown, yellowish-brown, pinchbeck-brown, wood-brown.

*A play of colours*.—This expression is used when several prismatic colours appear in rapid succession on turning the mineral. The diamond is a striking example; also precious opal.

*Change of colours*—when the colours change slowly on turning in different positions, as in labradorite.

*Opalescence*—when there is a milky or pearly reflection from the interior of a specimen, as in some opals, and in cat's-eye.

*Iridescence*—when prismatic colours are seen within a crystal; it is the effect of fracture, and is common in quartz.

*Tarnish*—when the surface colours differ from the interior; it is the result of exposure. The tarnish is described as irised when it has the hues of the rainbow.

3. *Asterism*.—Some crystals, especially the hexagonal, when viewed in the direction of the vertical axis, present peculiar reflections in six radial directions. This arises either from peculiarities of texture along the axial portions, or from some impurities. A remarkable example of it is that of the asteriated sapphire, and the quality adds much to its value as a gem. The six rays are sometimes alternately shorter, indicating the rhombohedral character of the crystal.

4. *Phosphorescence*.—Several minerals give out light either by friction or when gently heated. This property of emitting light is called phosphorescence.

Two pieces of white sugar struck against one another give a feeble light, which may be seen in a dark place. The same effect is obtained on striking together fragments of quartz; and even the passing of a feather rapidly over some specimens of zinc-blende is sufficient to elicit light.

Fluorite is the most convenient mineral for showing phosphorescence by heat. On powdering it and throwing it on a plate of metal heated nearly to redness, the whole takes a bright glow. In some varieties the light is emerald-green; in others, purple, rose, and orange. A massive fluor, from Huntington, Connecticut, shows beautifully the emerald-green phosphorescence. Some kinds of white marble, treated in the same way, give out a bright-yellow light. After being heated for a while the mineral loses its phosphorescence; but a few electric shocks will, in many cases, to some degree restore it again.

## ELECTRICITY AND MAGNETISM. (Dana.)

**Electricity.**—Many minerals become electrified on being rubbed, so that they will attract cotton and other light substances; and when electrified, some exhibit positive and others negative electricity when brought near a delicately suspended magnetic needle. The diamond, whether polished or not, always exhibits positive electricity, while other gems become negatively electric in the rough state, and positively only in the polished state. Some minerals, thus electrified, retain the power of electric attraction for many hours, as topaz, while others lose it in a few minutes.

Many minerals become electric when heated, and such species are said to be pyroelectric, from the Greek *pur*, fire, and electric.

A prism of tourmaline, on being heated, becomes polar, opposite electricity being developed in the extremities by the heat. The prisms of tourmaline have different secondary planes at the two extremities.

Several other minerals have this peculiar electric property, especially boracite and topaz, which, like tourmaline, are hemihedral in their modification. Boracite crystallises in cubes, with only the alternate solid angles similarly replaced. Each solid angle, on heating the crystals, become an electric pole; the angles diagonally opposite are differently modified, and have opposite polarity. Pyroelectricity has been observed also in crystals that are not hemihedral, and in many mineral species. In some cases the number of poles is more than two. In prehnite crystals a large series occur distributed over the surface.

**Magnetism.**—The name lodestone is given to those specimens of an ore of iron called magnetite which have the power of attraction like a magnet; it is common in many beds of magnetite. When mounted like a horseshoe-magnet, a good lodestone will lift a weight of many pounds. This is the only mineral that has decided magnetic attraction. But several ores containing iron are attracted by the magnet, or, when brought near the magnetic needle, will cause it to vibrate; and moreover, the metals nickel, cobalt, manganese, palladium, platinum, and osmium, have been found to be slightly magnetic.

Many iron-bearing minerals become attractable by the magnet after being heated that are not so before heating. This arises from a change of part or all of the iron to the magnetic oxide.

## FLAVOUR AND ODOUR. (Dana.)

Flavour belongs only to the soluble minerals. The kinds are—

1. *Astringent*—that of vitriol.
2. *Sweetish-astringent*—that of alum.

*Flavour and Odour—continued.*

3. *Saline*—that of common salt.
4. *Alkaline*—that of soda.
5. *Cooling*—that of saltpetre.
6. *Bitter*—that of Epsom salts.
7. *Sour*—that of sulphuric acid.

Odour is not given off by minerals in the dry, unchanged state, except in the case of a few gases and soluble minerals. By friction, moistening with the breath, the action of acids, and the blowpipe, odours are sometimes obtained which are thus designated:—

1. *Alliacous*—the odour of garlic. It is the odour of burning arsenic, and is obtained by friction, and more distinctly by means of the blowpipe, from several arsenical ores.
2. *Horse-radish odour*—the odour of decaying horse-radish. It is the odour of burning selenium, and is strongly perceived when ores of this metal are heated before the blowpipe.
3. *Sulphureous*—odour of burning sulphur. Friction will elicit this odour from pyrites, and heat from many sulphides.
4. *Fetid*—the odour of rotten eggs or sulphuretted hydrogen. It is elicited by friction from some varieties of quartz and limestone.
5. *Argillaceous*—the odour of moistened clay. It is given off by serpentine and some allied minerals when breathed upon. Others, as pyrargillite, afford it when heated.

## CRYSTALLINE AGGREGATES. (Dana.)

The crystalline aggregates here included are the simple, not the mixed; that is, they are those consisting of crystalline individuals of a single species.

The crystalline individuals may be (1) distinct crystals; (2) fibres or columns; (3) scales or lamellæ; or (4) grains, either cleavable or not so.

1. *Consisting of distinct crystals*.—The distinct crystal may be either long or short prismatic, stout or slender to acicular (needle-like), and capillary (hair-like); or they may have any other forms of crystals. They may be aggregated (*a*) in lines; (*b*) promiscuously with open spaces; (*c*) over broad surfaces; (*d*) about centres. The various kinds of aggregates thus made are:—

*a. Filiform*.—Thread-like lines of crystals, the crystals often not well defined.

*b. Dendritic*.—Arborescent slender spreading branches, somewhat plant-like, made up of more or less distinct crystals, as in the frost on windows, and in arborescent forms of native copper, silver, gold, &c.

*Crystalline Aggregates—continued.*

*c. Reticulated.*—Slender prismatic crystals promiscuously crossing, with open spacings.

*d. Divergent.*—Free crystals radiating from a central point.

*e. Drusy.*—A surface is drusy when covered with implanted crystals of small size.

2. *Consisting of columnar individuals.*

*a. Columnar*, when the columnar individuals are stout.

*b. Fibrous*, when they are slender.

*c. Parallel fibres*, when the fibres are parallel.

*d. Radiated*, when the columns or fibres radiate from centres.

*e. Stellated*, when the radiations from a centre are equal around, so as to make star-like or circularly-radiated groups.

*f. Globular*, when the radiated individuals make globular or hemispherical forms, as in wavellite.

*g. Botryoidal*, when the globular forms are in groups, a little like a bunch of grapes. The word is from the Greek for a bunch of grapes.

*h. Mammillary*, having a surface made up of low and broad prominences. The term is from the Latin *mammilla*, a little teat.

*i. Coralloidal*, when in open-spaced groupings of slender stems, looking like a delicate coral. A result of successive additions at the extremity of a prominence, lengthening it into cylinders, the stems generally having a faintly radiated structure.

Specimens of all these varieties of columnar structure, excepting the last, often having a drusy surface, the fibres or columns ending in projecting crystals.

3. *Consisting of scales or lamellæ.*

*a. Plumose*, having a divergent arrangement of scales, as seen on a surface of fracture; plumose mica.

*b. Lamellar, tabular*, consisting of flat lamellar crystalline individuals, superimposed and adhering.

*c. Micaceous*, having a thin fissile character, due to the aggregation of scales of a mineral which, like mica, has eminent cleavage.

*d. Septate*, consisting of openly-spaced intersecting tabular individuals; also divided into polygonal portions by reticulating veins or plates. A septarium is a concretion, usually flattened spheroidal in shape, the solid interior of which is intersected by partitions; these partitions are the fillings of cracks in the interior that were due to contraction on drying. Such septate concretions, especially when worn off at surface, often have the appearance of a turtle's back, and are sometimes taken for petrified turtles.

4. *Consisting of Grains. Granular structure.*—A massive mineral may be coarsely granular or finely granular, as in varieties of marble, granular quartz, &c. It is termed saccharoidal when evenly granular, like loaf-sugar. It may also be cryptocrystalline, that is, having no distinct grains that can be detected by the unaided eye, as in flint. The term cryptocrystalline is from the Greek for concealed crystalline. Aphanitic, from the Greek for

*Crystalline Aggregates—continued.*

invisible, has the same signification. The term ceroid is applied when this texture is connected with a waxy lustre, as in some common opal.

Under this section occur also globular, botryoidal, and mammillary forms, as a result of concretionary action in which no distinct columnar interior structure is produced. They are called pisolitic when in masses consisting of grains as large as peas (from the Latin *pisum*, a pea), and oölitic when the grains are not larger than the roe of a fish, from the Greek for egg.

5. *Forms depending on mode of deposition.*—Besides the above, there are the following varieties which have come from mode of deposition :—

*a. Stalactitic*, having the form of a cylinder, or cone, hanging from the roofs of cavities or caves. The term stalactite is usually restricted to the cylinders of calcium carbonate hanging from the roofs of caverns; but other minerals are said to have a stalactitic form when resembling these in their general shape and origin. Chalcedony and limonite are often stalactitic. Interiorly the structure may be either granular, radiately fibrous, or concentric.

The waters percolating through the roofs of limestone caverns hold some limestone in solution; and the deposit which each successive drop of water makes, lengthens out the cylinder; and not unfrequently they become yards in length, or reach from roof to floor. The stalactites are sometimes hollow cylinders when small, because the drops, which follow one another very slowly, evaporate chiefly at the outer margin of each, the first one thus making a ring, and the following lengthening the ring into the cylinder. The solution is strictly a solution of calcium bicarbonate; as evaporation takes places the excess of carbonic acid goes off and calcium carbonate is deposited.

*b. Concentric.*—When consisting of lamellæ, lapping one over another around a centre, a result of successive concretionary aggregations, as in many concretionary forms, most pisolite, part of oölite, some stalactites, &c.

*c. Stratified*, consisting of layers, as a result of deposition: e.g. some travertine, or tufa.

*d. Banded, straticulate*; colour-stratified. Like stratified in origin, but the layers thin and usually indicated only by variations in colour or texture; the banding is shown in a transverse section: e.g., agate, much stalagmite, riband jasper, some limestone; it becomes lamellar or slaty when the little layers are separable.

*e. Geodes.*—When a cavity has been lined by the deposition of mineral matter, but not wholly filled, the enclosing mineral is called a geode. The mineral is often banded, owing to the successive depositions of the material, and frequently has its inner surface set with crystals. Agates are often slices or fragments of geodes.

6. *Fracture.*—Kinds of fracture in these crystalline aggregates

*Crystalline Aggregates*—continued.

depend on the size and form of the particles, their cohesion, and to some extent their having cleavage or not.

Among granular varieties, the influence of cleavage is in all cases very small, and in the finest almost or quite nothing. The term "hackly" is used for the surface of fracture of a metal, when the grains are coarse, hard, and cleavable, so as to be sharp and jagged to the touch; even, for any surface of fracture when it is nearly or quite flat, or not at all conchoidal; conchoidal, when the mineral, owing to its extremely fine or crypto-crystalline texture, breaks with shallow concavities and convexities over the surface, as in the case of flint. The word conchoidal is from the Latin *concha*, a shell. These kinds of fracture are not of great importance in mineralogy, since they distinguish varieties of minerals only, and not species.

## FUSIBILITY. (Foye.)

1. Stibnite (grey antimony). Fusible in coarse splinters in the summit of a candle-flame without the blow-pipe.
2. Natrolite. Fusible in fine splinters in the summit of a candle-flame without the blow-pipe.
3. Almandite (iron-alumina-garnet). Does not fuse in the candle-flame. Fuses easily before the blow-pipe in obtuse pieces.
4. Green Actinolite. Fusible before the blow-pipe in coarse splinters.
5. Orthoclase. Fusible before the blow-pipe in fine splinters.
6. Bronzite. Before the blow-pipe, becomes rounded only on the sharp edges.

Table

Name.	H.	Tenacity.	Diaphaneity.	Lustre.	Colour.
Diamond .. .. .	10	..	Transparent to translucent.	Adamantine	White to shades of yellow, orange, red, blue, green, brown, black.
Emerald .. .. .	7½-8	Brittle	Transparent to subtranslucent	Vitreous to resinous.	Rich green
Lapis-lazuli .. .. .	5½	..	Transparent to opaque.	Vitreous	Rich blue
Opal .. .. .	5½-6½	..	Rich play of colours when turned.	Waxy to sub-vitreous.	White, grey, yellow, brown, red, green, blue.
Sapphire .. .. .	9	Very tough	Transparent to translucent.	..	Blue as a rule.
Topaz .. .. .	8	..	Transparent to subtranslucent	Vitreous	Pale yellow.
Turquoise .. .. .	6	..	..	Waxy	Bluish green.

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Electricity and Magnetism.	Structure.	Sp. gr.	B.B.	Solubility.	Composition.	Application.
Vitreous electric when rubbed.	Crystalline, isometric.	3·00–3·55	Burns away as carbonic acid gas.	Insoluble	Pure carbon	Jewelry, cutting and drilling.
..	Crystalline, hexagonal.	2·67–2·75	Clouded, but not fused.	Insoluble	Silica 62 Alumina 19 Beryllium oxide } 16	Jewelry.
..	Massive, rarely crystalline (isometric).	2·3–2·5	Fuses to white glass.	When powdered and calcined loses colour in acids.	Silica 45 Alumina 32 Soda 9 Lime 3 Iron 1 Sulphuric acid } 6 Sulphur 1 Silica	Jewelry, Ornaments, Mosaics.
..	Compact, amorphous.	1·9–2·3	..	In strong alkaline solution.		Jewelry.
..	Crystalline, rhombohedral.	3·94–4·16	Unaltered both alone and with soda.	..	Aluminium 53 Oxygen 47	Jewelry.
Pyro-electric	Crystalline, orthorhombic.	3·4–3·65	Infusible	Insoluble in acids.	Alumina 57 Silica 34 Fluorine 15	Jewelry.
..	Massive ..	2·6–2·8	Infusible, becomes brown, colours flame green.	In hydrochloric acid.	Phosphorus 22½ Alumina 47 Water 20½	Jewelry.



Table

Name.	II.	Tenacity.	Diaphaneity.	Lustre.	Colour.	Streak.	Electricity and Magnetism.
<b>ALUMINIUM—</b>							
Alum shale ..	..	..	..	..	..	..	..
Alum stone ..	4	..	Transparent to translucent.	Vitreous to pearly.	White to reddish.	..	..
Corundum ..	9	Exceedingly tough.	Transparent to translucent.	..	Blue to black.	..	..
Cryolite ..	..	..	Translucent	..	White	..	..
Emerald ..	9	Exceedingly tough.	Transparent to translucent.	..	Black	..	..
<b>ANTIMONY</b> ..	3-3½	Brittle	..	..	White	White	..
Stibnite ..	2	Brittle	..	Shining	Grey	Grey, tarnishes	..
<b>BARIUM—</b>							
Barytes ..	2½-3½	..	Transparent to translucent.	Vitreous to pearly.	White	..	..
Witherite ..	3½	Brittle	Transparent to translucent.	Resinous	Dirty white.	..	..
<b>BISMUTH</b> ..	2-2½	Brittle	..	..	White	White	..
<b>CHROMIUM—</b>							
Chromite ..	5½	..	..	Submetallic	Brownish black.	Dark brown.	Magnetic in small fragments.

Flavour and Odour.	Structure.	Sp. gr.	B.B.	Effervescence.	Solubility.	Composition.	Application.
..	Massive and crystalline (rhombohedral).	2.58-2.75	Infusible, decrepitates.	..	In sulphuric acid complete without forming jelly.	Alumina 37 Potash 11 Sulphurous oxide } 38 Water 13	Affords Roman alum, much prized by dyers.
..	Crystalline, rhombohedral.	3.94-4.16	Unaltered alone or with soda.	..	..	Pure alumina	Abrasive purposes.
..	Monoclinic	2.9-3.1	Fusible in candle-flame.	..	..	Fluorine 54 Sodium 33 Aluminium 13	Source of aluminium; used in soda and glass making.
..	..	3.94-4.16	Unaltered alone or with soda.	..	..	Alumina containing magnetic iron.	Abrasive purposes.
..	Crystalline, rhombohedral.	6.6-6.75	Fuses easily and vaporises.	..	..	Contains a little arsenic, iron, and silver as impurities.	Alloys and medicine.
..	Crystalline, orthorhombic.	4.5-4.62	Fuses in candle-flame; vaporises and gives white sulphurous fumes on charcoal.	..	..	Antimony 72 Sulphur 28	Chief source of antimony.
..	Crystalline, orthorhombic.	4.3-4.7	Fuses to a bead and colours flame green.	..	Insoluble in acids.	Baryta 66 SO <sub>3</sub> 34	Common pigment.
..	Crystalline, orthorhombic.	4.29-4.35	Fuses to a bead and colours flame green; also decrepitates.	In HCl	Soluble in acids.	Baryta 78 CO <sub>2</sub> 22	In sugar refining and plate-glass making.
..	Crystalline, rhombohedral.	9.7-9.8	Vaporises, leaving a yellow coating; fuses at 476° F.	..	..	Arsenic, sulphur, and tellurium as impurities.	Alloys.
..	..	..	Infusible alone; green bead with borax.	..	..	Chromium oxide } 68 Iron oxide 32	Source of chrome green and chrome yellow; valuable pigments.

# METALS AND

Table 135

Name.	H.	Tenacity.	Diaphaneity.	Lustre.	Colour.	Streak.	Electricity and Magnetism.
COBALT— Black oxide..	..	..	..	..	Blue-black.	..	..
Bloom .. ..	1½-2	..	Transparent to translucent.	Pearly to none.	Red	..	..
Glance .. ..	5½-6	Brittle	..	..	White	Greyish	..
COPPER .. ..	2½-3	Ductile, malleable.	..	..	Reddish	..	..
Black .. ..	..	..	..	..	Black	..	..
Blue vitriol ..	2-2½	..	Subtrans- parent to translucent.	Vitreous	Deep blue.	Uncoloured.	..
Glance .. ..	2½-3	..	..	..	Grey	Grey	..
Grey .. ..	3-4½	..	..	..	Grey to blackish.	..	..
Horseflesh ore	3	Brittle	..	..	Reddish brown, tarnishes.	Greyish black, shining.	..
Malachite (a)	3½-4	..	Opaque	..	Light green.	Pale green	..

—continued.

Flavour and Odour.	Structure.	Sp. gr.	B.B.	Effervescence.	Solubility.	Composition.	Application.
..	Earthy	..	..	..	In HCl. giving chlorine fumes.	Cobalt oxide, 20-40 %	Pigment.
..	Crystalline, monoclinic	2.95	Fuses with arsenical fumes on charcoal; gives blue glass with borax.	..	..	Cobalt oxide } 38 Arsenic acid } 38 Water 24	Pigment.
..	Crystalline, isometric.	6.4-7.2	Fuses to globule, emitting arsenical fumes; gives metallic arsenic in closed tube.	..	..	23½ % cobalt to nil.	Pigment, and affords nickel.
..	..	8.8-8.95	Fuses readily at 1930° F., surface black on cooling.	..	In nitric acid, giving deep blue with ammonia.	A little silver as an impurity	Many industrial purposes both alone and in alloys.
..	Powder and in masses.	..	..	..	..	Copper oxide, giving 60-70 % metal.	Source of the metal.
Nauseous metallic taste.	Crystalline, triclinic.	2.21	..	..	..	Copper oxide } 32 SO <sub>3</sub> 32 Water 36	Source of the metal, and used in dyeing, calico printing, and as an antiseptic.
	Crystalline, orthorhombic.	5.5-5.8	Fuses readily, giving sulphur fumes leaving metallic globule.	..	In hot nitric acid.	Copper 80 Sulphur 20	Source of the metal.
..	..	4.7-5	..	..	..	Often contains silver.	Source of the metal.
..	Crystalline, isometric.	4.4-5.5	Fuses to brittle magnetic globule.	..	In nitric acid.	Copper 55½ Iron 16½ Sulphur 28½	Source of the metal.
..	Crystalline, monoclinic.	3.7-4	Decrepitates, colours flame green and forms black slag; with borax fuses and gives metallic bead.	In nitric acid.	In nitric acid.	Copper oxide } 72 CO <sub>2</sub> 20 Water 8	Source of the metal, and in ornamentation.

Table 135

Name.	H.	Tenacity.	Diaphaneity.	Lustre.	Colour.	Streak.	Electricity and Magnetism.
<b>COPPER—</b> Malachite (b)	3½-4½	Brittle	Transparent to opaque.	Vitreous to adamantine.	Deep blue.	Bluish	..
Pyrites .. ..	3½-4	Brittle	..	..	Yellow, iridescent, darker colour richer in copper.	Greenish black.	..
Silicate .. ..	2-4	..	Translucent to opaque.	Shining to earthy.	Bluish green.	..	..
<b>GOLD</b> .. ..	2½-3	Very ductile and malleable.	..	..	Yellow to whitish.	..	..
Calaverite .. ..	..	..	..	..	Bronze yellow.	..	..
Sylvanite .. ..	1½-2	..	..	..	Grey to yellow.	Grey to yellow.	..
<b>IRON—</b> Hematite .. ..	5½-6½	..	..	Splendent when crystallised.	Grey to black.	Reddish brown.	Sometimes slightly magnetic.
Limonite .. ..	5-5½	..	..	Submetallic to earthy.	Blackish to yellow.	Yellowish.	..
Magnetite .. ..	5½-6½	Brittle	..	..	Black	Black	Strongly magnetic.
Siderite .. ..	3-4½	..	Translucent to opaque.	Pearly	Greyish to brownish red.	..	..

—continued.

Flavour and Odour.	Structure.	Sp. gr.	B.B.	Effervescence.	Solubility.	Composition.	Application
..	Crystalline, monoclinic.	3.5-3.83	Decrepitates, colours flame green and forms black slag; with borax fuses and gives metallic bead.	In nitric acid.	In nitric acid.	Copper oxide } 70 CO <sub>2</sub> 23 Water 5	Source of metal.
..	Crystalline, tetragonal.	4.15-4.3	Gives sulphur fumes; and metallic globule of copper and iron with soda on charcoal.	..	In nitric acid.	Copper 34½ Iron 30½ Sulphur 35	Sulphur burned off to make sulphuric acid and cinders treated for copper.
..	Massive; incrustations.	2-2.4	Gives water without melting; affords metallic globule with soda on charcoal.	..	..	Copper oxide } 45 Silica 34 Water 20	Gives 10-30% of metal.
..	..	19-19.3	Melts without odour at 2016° F.	..	In aqua regia.	Always contains some silver.	Coin, jewelry, &c.
..	Massive	9.043	..	..	..	Tellurium 55½ Gold 44½	Source of gold.
..	..	7.9-8.33	..	..	..	Tellurium 56 Gold 28½ Silver 15½	Source of gold.
..	Crystalline, rhombohedral, to massive and earthy.	4.5-5.3	Infusible, becomes magnetic.	..	..	Iron 70 Oxygen 30	Valuable source of metal; earthy varieties used as pigments.
..	Massive to earthy.	..	Blackens and becomes magnetic; forms a yellow glass with borax in outer flame.	..	..	Iron oxide 85½ Water 14½	Valuable source of metal; earthy varieties used as pigments.
..	Crystalline, isometric.	5-5.1	Infusible; gives yellow glass with borax in outer flame.	..	..	Iron 72½ Oxygen 27½	Valuable source of metal.
..	Crystalline, rhombohedral.	3.7-3.9	Infusible, blackens, becomes magnetic.	In HCl	In hot HCl	Iron oxide 62 Carbon oxide } 38	Valuable source of metal.

Table 135

Name.	H.	Tenacity.	Diaphaneity.	Lustre.	Colour.	Streak.	Electricity and Magnetism.
LEAD— Cerussite ..	3-3½	Brittle	..	Adamantine	White to dark grey.	..	..
Galena .. ..	2½	Fragile	..	Shining metallic.	Grey	Grey	..
MANGANESE— Fowlerite ..	5½-6½	..	Transparent to opaque.	Vitreous	Reddish to black.	..	..
Pyrolusite ..	2-2½	..	..	..	Black	Black, non-metallic.	..
MERCURY— Cinnabar ..	2-2½	Seftile	Subtransparent to opaque.	Dull to adamantine.	Red to brownish black.	Scarlet to brownish.	..
NICKEL— Linnaite ..	5½	..	..	..	Grey	Grey	..
Millerite ..	3-3½	Brittle	..	..	Yellow	Bright	..
Niccolite ..	5-5½	Brittle	..	Metallic	Red	Red	..
Pyrrhotite ..	3½-4½	Brittle	..	..	Yellowish red.	Greyish black.	Slightly magnetic.
Smaltite, see Cobalt glance							

—continued.

Flavour and Odour.	Structure.	Sp. gr.	B.B.	Effervescence.	Solubility.	Composition.	Application.
..	Crystalline, orthorhombic.	6·46–6·48	Fuses, decrepitates, gives bead on charcoal with difficulty.	In dilute nitric acid.	In dilute nitric acid.	Lead oxide 83½ Carbon oxide } 16½	Valuable source of metal.
..	Crystalline, isometric.	7·25–7·35	Fuses, decrepitates, emits sulphur, gives charcoal a yellow coating, and yields metallic bead.	..	..	Lead 86½ Sulphur 13½	Valuable source of metal; and often silver.
..	Crystalline, triclinic.	3·4–3·7	Deep violet borax bead, becoming reddish brown on cooling.	..	..	Manganese oxide } 54 Silica 46	As an ornamental stone, and in staining glass and porcelain.
..	Crystalline, orthorhombic.	4·8	Deep violet borax bead, becoming reddish brown on cooling.	..	..	Manganese 63 Oxygen 37	In making bleaching powder.
..	Crystalline, rhombohedral.	8–9	Quite volatile.	..	..	Mercury 86 Sulphur 14	Chief source of the metal.
..	Crystalline, isometric.	4·8–5	Gives sulphurous and arsenical fumes and affords metallic globule on charcoal.	..	..	Sulphur 42 Nickel and Cobalt, various	Source of nickel.
..	Crystalline, rhombohedral.	5·65	Fuses to globule on charcoal.	..	..	Nickel 64½ Sulphur 35½	Source of nickel.
..	Crystalline, hexagonal.	7·35–7·67	Fuses to globule, emits arsenical fumes.	..	In aqua regia.	Nickel 44 Arsenic 56	Source of nickel.
..	Crystalline, hexagonal.	4·5–4·65	Fuses and glows in inner flame, affording black magnetic globule.	..	..	Iron 60½ Sulphur 39½ Nickel, varying.	Source of nickel.



Table 135

Name.	H.	Tenacity.	Diaphaneity.	Lustre.	Colour.	Streak.	Electricity and Magnetism.
PALLADIUM ..	4½-5	Ductile, malleable.	..	Steel-like when hammered.	Grey to white.	..	..
PLATINUM ..	4-4½	Ductile, malleable.	..	Metallic, shining.	Grey	Grey	Often magnetic.
SILVER .. ..	2½-3	Sectile, malleable.	..	..	White, shining.	White, shining.	..
Black .. ..	2-2½	Brittle	..	..	Black	Black	..
Embolite ..	1-1½	..	..	..	Green	..	..
Galena, <i>see</i> Lead, galena Glance .. ..	2-2½	Sectile	..	Metallic	Grey	Grey, shining.	..
Horn .. ..	1½-2	..	Transparent to opaque.	Resinous to adamantine.	Grey to greenish or bluish.	Shining	..
Polybasite ..	..	..	..	..	Blackish	..	..
Proustite ..	..	..	..	Splendent	Light red.	..	..
Ruby .. ..	2-2½	..	..	Splendent to adamantine.	Black to dark red.	..	..
STRONTIUM— Celestite ..	3-3½	Brittle	Transparent to translucent.	Vitreous to pearly.	Bluish white.	..	..

—continued.

Flavour and Odour.	Structure.	Sp. gr.	B.B.	Effervescence.	Solubility.	Composition.	Application.
..	..	11·3–12·2	Fuses with sulphur.	..	..	Contains platinum and iridium.	Forms valuable alloys for instruments.
..	Grains or masses.	16–19	Unaltered	..	Hot aqua regia.	..	Invaluable for instruments and chemical plant, used in electricity and photography.
..	Crystalline, isometric.	10·1–11·1	Easily fuses to white globule.	..	Nitric acid	Often contains copper, sometimes bismuth.	Coin, plate, &c.
..	Crystalline, orthorhombic.	6·27	Fumes of sulphur and antimony.	..	Dilute nitric acid.	Silver 68½ Antimony 15 Sulphur 16	Source of metal.
..	..	5·3–5·8	..	..	..	Silver } chloride } ,, bromide 41	Source of metal.
..	Crystalline, isometric.	7·19–7·4	Intumesces, emits sulphur and gives metallic bead on charcoal in outer flame.	..	..	Silver 87 Sulphur 13	Coin, plate, &c.
..	Crystalline, isometric.	..	Fuses in candle, emitting acrid fumes; gives metal on charcoal.	..	..	Silver 75 Chlorine 25	Source of metal.
..	Crystalline, orthorhombic.	6·214	..	..	..	Silver 64–72%	Source of metal.
..	..	5·4–5·6	Garlic odour	..	..	Silver 65½ Arsenic 15 Sulphur 19½	Source of metal.
..	Crystalline, rhombohedral.	5·7–5·9	Fuses very readily; gives white deposit on charcoal and metallic bead with soda.	..	..	Silver 60 Antimony 22½ Sulphur .. 17½	Source of metal.
..	Crystalline, orthorhombic.	3·9–4	Decrepitates and fuses, colouring flame red.	..	..	Strontia } Sulphuric acid } 43½	Colouring fireworks.

Table 135

Name.	H.	Tenacity.	Diaphanely.	Lustre.	Colour.	Streak.	Electricity and Magnetism.
STRONTIUM— Strontianite..	3½-4	Brittle	Transparent to translucent.	Vitreous to resinous.	Greenish white.	..	..
TELLURIUM ..	2-2½	Brittle	..	..	White	White	..
TIN— Ore .. ..	6-7	..	Translucent to opaque.	Adamantine	Brown to black.	Grey to brownish	..
Pyrites .. ..	4	Brittle	..	..	Grey to black.	Blackish	..
TITANIUM— Rutile .. ..	6-6½	Brittle	Transparent to opaque.	Submetallic to adamantine.	Reddish	Brownish.	..
TUNGSTEN— Wolfram ..	5-5½	..	..	Submetallic to shining.	Dark grey.	Reddish brown	..
URANIUM— Pitchblende ..	5½	..	Opaque	Submetallic to dull.	Grey to black.	Black	..
Uran mica ..	2-2½	..	Transparent to subtranslucent.	Pearly	Green	Green	..
ZINC— Blende .. ..	3½-4	Brittle	Transparent to subtranslucent.	Resinous to waxy.	Yellow to black.	..	Frictionally electric.
Calamine ..	4½-5	Brittle	Transparent to subtranslucent.	Vitreous to pearly.	Dirty whitish.	..	Pyro-electric.

—continued.

Flavour and Odour.	Structure.	Sp. gr.	R.B.	Effervescence.	Solubility.	Composition.	Application.
..	Crystalline, orthorhombic.	3.6–3.72	Swells but does not fuse; colours flame red.	In cold dilute acid.	..	Strontia 70 Carbonic acid } 30	Colouring fireworks.
..	Crystalline, rhombohedral.	6.1–6.3	Fuses and volatilises on charcoal, giving green flame.	..	..	..	..
..	..	6.4–7.02	Infusible alone; with soda on charcoal gives metallic bead	..	..	Tin 78½ Oxygen 21½	Source of metal.
..	..	4.3–4.6	..	..	..	Tin 27 Copper 30 Iron 13 Sulphur 30 Titanium 61 Oxygen 39	Source of metal. Enamelling porcelain and teeth.
..	Crystalline, tetragonal.	4.18–4.25	Unaltered alone.	..	..	..	..
..	Crystalline, monoclinic.	7.1–7.5	Fuses easily to magnetic globule.	..	Aqua regia	Tungsten oxide } 76½ Manganese oxide } 14 Iron oxide 9½	Alloys with iron.
..	Crystalline, isometric.	6.4–9.3	Infusible; grey slag with borax.	..	Powder slowly in nitric acid.	Uranium 81½ Lead 4 Iron + Oxygen 13½ Water +	Enamelling porcelain.
..	Crystalline, tetragonal.	3.3–3.6	Fuses to blackish mass; colours flame green.	..	..	Uranium oxide } 61 Phosphorus oxide } 15 Copper „ 8½ Water „ 15½	Enamelling porcelain.
..	Crystalline, isometric.	..	Nearly infusible alone or with borax. Zinc fumes when strongly heated on charcoal.	..	Nitric acid	Zinc 67 Sulphur 33	Source of metal.
..	Crystalline, orthorhombic.	3.16–3.9	Infusible alone; clear glass with borax.	..	Hot sulphuric acid, gelatinising.	Zinc oxide 67½ Silica 25 Water 7½	Source of metal.

Table 135

Name.	H.	Tenacity.	Diaphaneity.	Lustre.	Colour.	Streak.	Electricity and Magnetism.
ZINC— Goslarite ..	2-2½	Brittle	..	Vitreous	White	..	..
Smithsonite ..	5	Brittle	Subtrans- parent to translucent.	Vitreous to pearly.	Dirty white.	..	Frictional- ly electric, negative.
Willemite ..	5½	Brittle	Transparent to opaque.	..	Dirty white.	..	..
Zincite ..	4-4½	..	Translucent	Brilliant to subadam- antine.	Red	Yellow.	..

Table

## NON-METALLIFEROUS

Name.	H.	Tenacity.	Diaphaneity.	Lustre.	Colour.	Streak.	Electricity and Magnetism.
APATITE ..	5	Brittle	Transparent to opaque.	Vitreous to resinous.	Greenish	..	Frictional- ly electric.
ARSENIC..	3-5	Brittle	..	..	Dirty white.	Dirty white.	..
Mispickel ..	5½-6	Brittle	..	Shining	White	Grey	..
Orpiment ..	1½-2	Secile	Transparent to translucent.	Pearly	Yellow	Yellow	..
Realgar ..	1½-2	..	Transparent to translucent.	..	Orange to red.	..	..

—continued.

Flavour and Odour.	Structure.	Sp. gr.	B.B.	Effervescence.	Solubility.	Composition.	Application.
Astringent, metallic, nauseous	Crystalline, orthorhombic.	2.036	Zinc fumes on charcoal.	..	Easily	Zinc oxide 28 Sulphuric acid } 28 Water 44	Dyeing, and as a disinfectant.
..	Crystalline, rhombohedral.	4.3-4.45	Infusible alone; finally vaporises.	..	..	Zinc oxide 65 Carbonic acid } 35	Source of metal.
..	Crystalline, rhombohedral.	3.89-4.18	Difficultly fusible to white enamel	In nitric acid	In HCl gelatinises	Zinc oxide 73 Silica 27	Source of metal.
..	Crystalline, hexagonal.	5.68-5.74	Infusible alone; yellow transparent bead with borax.	..	In nitric acid.	Zinc 80 Oxygen 20	Source of metal.

136.

## MINERALS.

Flavour and Odour.	Structure.	Sp. gr.	B.B.	Effervescence.	Solubility.	Composition.	Application.
..	Hexagonal	3.18-3.25	Fusible only on edges.	None	Slowly in nitric acid.	Phosphorus oxide 41 Lime 54 Chlorine or Fluorine ..	Artificial manures.
..	Rhombohedral.	5.65-5.95	Readily volatilises, with garlic odour.	..	..	..	In alloys.
..	Orthorhombic.	5.67-6.3	Arsenical fumes, magnetic globule.	..	..	Arsenic 46 Iron 344 Sulphur 194	Affords arsenic and often cobalt and gold.
..	Orthorhombic.	3.4-3.5	Evaporates with garlic odour; burns with blue flame on charcoal.	..	..	Arsenic 61 Sulphur 39	Pigment.
..	..	3.35-3.65	Evaporates with garlic odour; burns with blue flame on charcoal.	..	..	Arsenic 70 Sulphur 30	Pyrotechny.

Table 136

Name.	H.	Tenacity.	Diaphaneity.	Lustre.	Colour.	Streak.	Electricity and Magnetism.
ARSENIC— White .. ..	1½	..	..	..	White	..	..
ASBESTOS .. ..	..	..	Translucent	Vitreous to pearly.	White to brownish green	..	..
BORATES— Lime .. ..	3	..	..	..	..	..	..
Lime-soda .. ..	1	..	..	Silky	Dirty white.	..	..
Magnesia .. ..	7	..	..	Vitreous	Dirty white.	..	Pyro-electric.
Soda .. ..	2-2½	..	Transparent	Vitreous	White	..	..
CALCESPAR .. ..	3	..	..	Silky to vitreous and earthy.	White to nearly black.	..	..
EPSOM SALT .. ..	..	..	..	Vitreous to earthy.	White	..	..
FLUOR SPAR .. ..	4	Brittle	Transparent to sub-translucent.	..	Greenish purplish, yellowish.	..	..
GRAPHITE .. ..	1-2	Flexible in thin laminae.	..	Metallic	Black to grey.	Soils paper.	..
GIPSUM .. ..	1½-2	..	Transparent to opaque.	Pearly	Dirty white.	..	..

—continued.

Flavour and Odour.	Structure.	Sp. gr.	B.B.	Effervescence.	Solubility.	Composition.	Application.
Sweetish astringent.	Isometric	3·7	..	..	Readily	Arsenic 76 Oxygen 24	Medicine.
..	Fibrous, silky.	2·9–3·4	Unalterable	..	..	..	Fireproofing.
..	..	2·262–2·48.	..	..	..	..	Borax (borate of soda)
..	Fibrous	1·65	Fuses very easily.	..	..	..	is much used in
..	Isometric	2·97	Easily fused; intumesces; colours flame green.	..	In HCl.	Boron oxide } 62 Magnesia 31 Chlorine 7	medicine and for preserving foods;
Sweetish alkaline.	..	..	Swells enormously, becomes opaque, and finally forms glassy bead.	..	..	Boron oxide } 36½ Soda 16½ Water 47½	the other borates are converted into borax for similar uses.
..	..	2·5–2·8	Infusible; colours flame reddish; becomes caustic.	Dilute cold HCl	..	Lime 56 Carbonic acid } 44	Common forms, as chalk and limestone, afford lime; marbles used in ornamental buildings; Iceland spar used in optical instruments.
Saline bitter.	..	..	..	..	Very readily.	Magnesia 16½ Sulphuric acid } 32½ Water 51	Medicine.
..	Isometric	3–3·25	Decrepitates; fuses to an enamel.	..	Powder in sulphuric acid.	Fluorine 49 Calcium 51	As a flux; for carving; vapour etches glass.
Greasy touch.	Hexagonal	2·25–2·27	Infusible	..	Insoluble	Carbon 95–99%	Crucibles, furnaces, pencils.
..	Monoclinic	2·33	Exfoliates; becomes white and opaque; forms globule.	..	Quietly in HCl	Lime 32½ Sulphuric acid } 46½ Water 21	For carving; manure; and plaster of Paris.



Table 136

Name.	H.	Tenacity.	Diaphaneity.	Lustre.	Colour.	Streak.	Electricity and Magnetism.
INFUSORIAL EARTH } ..	..	..	..	..	Dirty white.	..	..
KAOLIN .. ..	1-2½	Flexible	..	..	Dirty white.	..	..
MEERSCHAUM	2-2½	..	..	..	Whitish	..	..
MICA .. ..	2-2½	Tough, elastic.	Transparent to translucent.	Pearly	Yellowish brown.	..	..
NITRATES—Potash .. ..	2	..	..	..	Dirty white.	..	..
Soda .. ..	..	..	..	..	Dirty white.	..	..
SALT .. ..	2	..	..	..	Dirty white.	..	..
SULPHUR .. ..	1½-2½	Brittle	Transparent to translucent.	Resinous	Yellow	Yellow	..
Pyrites .. ..	6-6½	Brittle	..	Metallic	Yellow	Brownish.	..
TALC .. ..	1-1½	Flexible	..	Pearly	Greenish	..	..

—continued.

Flavour and Odour.	Structure.	Sp. gr.	B.B.	Effervescence.	Solubility.	Composition.	Application.
..	Earthy	..	..	..	..	Silica	Polishing; boiler covering; making soluble silica
Greasy touch.	Orthorhombic.	2·4–2·6	Infusible	..	Insoluble	Alumina 40 Silica 46 Water 14	Porcelain; paper-making.
Smooth touch.	..	Floats on water.	Infusible	..	..	Silica 61 Magnesia 27 Water 12	Pipe bowls.
..	Monoclinic	2·7–3	Whitens; fuses only on thinnest edges.	..	..	Silica 46 Alumina 38 Iron 4 Potash 9 Water 2	In heat-resisting structures.
Saline, cooling.	Orthorhombic.	1·97	Burns vividly.	..	In water	Potash 46½ Nitrogen oxide } 63½	Explosives; nitric acid; pyrotechnics
Saline, cooling.	Rhombohedral.	..	Burns vividly; deliquesces.	..	In water	Soda 36½ Nitrogen oxide } 63½	Making nitric & sulphuric acids; manures.
Saline	Isometric	2·257	Fuses easily; decrepitates; colours flame yellow.	..	In water	Chlorine 61 Sodium 39	Domestic; agricultural; industrial.
..	Orthorhombic.	2·07	Burns with blue flame and sulphurous odour.	..	..	..	Bleaching; gunpowder; sulphuric acid.
..	Isometric	4·8–5·2	Emits sulphur; affords magnetic globule.	..	..	Sulphur 53 Iron 47	Green vitriol; sulphuric acid; alum.
Greasy touch.	Orthorhombic.	2·5–2·8	Infusible	..	Insoluble	Silica 63 Magnesia 33 Water 3	Polishing; lubricating; fire resisting; porcelain; weighting paper and soap.

## ASSAYING.

ASSAYING: *Auriferous Mineral.* a. (Foord.)

The auriferous nature or otherwise of quartz may be readily ascertained by means for the most part mechanical; and we may often gain an insight into the mode of occurrence of the precious metal, and consequently as to the treatment which such a quartz would require in the mill. The mode of procedure is simply this. First pulverise the sample in a large cast-iron mortar, with a very stout bottom; the pestle of wrought iron may be 4 ft. long, and weigh 13 lb., and the upper part of this pestle, for preservation of the hands, should be covered with a short piece of rubber hose pipe. Employ a sieve of brass wire of fine mesh (say about 900 to the sq. in.), and after all the sample has passed through the sieve, grind the powder still finer in a shallow cast-iron mortar of about 11 in. diameter and 5 in. deep. Then submit a weighed quantity of the very finely ground sample to careful washing in a porcelain dish, and you will eventually obtain a residue consisting almost entirely of the metallic sulphides of the ore. These, small in bulk in proportion to that of the original quartz sample, are next transferred to a large agate mortar, again ground and washed alternately, until at last a small grey residue showing no gold is all that remains. This grey residue consists almost entirely of particles of cast and wrought-iron abraded during the preceding operations. They may be easily separated. A darning needle or a steel pen is magnetised by drawing it once or twice, always in the same direction, over the surface of an ordinary horse-shoe magnet, and to the little steel magnet thus obtained the particles of iron will attach themselves, and may be freed from any entangled particles of gold by drawing them backwards and forwards through the water with which the agate mortar is filled. The agate mortar is pre-eminently suitable for this final work; the smallest particle of gold can be seen against the dull surface of the agate; the hardest materials can be ground impalpably in the little vessel, and it serves the double capacity of mortar and wash-bowl; we can wash and grind alternately to the close of the operation. When the gold is finally separated in spangles or flattened particles in the agate mortar, accessory chemical means for refining and collecting the precious metal into a globule may be employed. The gold residue may be wrapped in a morsel of sheet-lead and cupelled before the blow-pipe; and from the diameter of the resulting minute spherical bead of fused gold thus obtained, its weight may be easily computed. Such operations would in most cases prove inapplicable in the hands of the miner in the field. But by the purely mechanical treatment, the miner can ascertain whether the sample tried is auriferous or not, and even without attempting to weigh the sepa-

*Auriferous Mineral*—continued.

rated gold, he will be able to draw valuable conclusions from its aspect in the mortar, concerning the comparative richness of the stone.

ASSAYING: *Auriferous Mineral*. b. (Panning.)

The estimation of the value of an auriferous material in which the gold is contained in a free state, can be done sometimes in a more satisfactory manner by simple appliances than in the best appointed laboratory. This is especially the case with low grade material, and arises from the fact that a laboratory assay can only be made on small samples, and that small samples cannot possibly be made to accurately represent the bulk, because the presence or absence of a small particle of gold in or from the same will suffice to disturb the basis of calculation. Panning more nearly resembles the operations which are put in practice when working the material as an industrial undertaking, and is therefore in many cases to be preferred. Of course, to be reliable, it must be done by an expert.

The implement most commonly used is the ordinary miners' pan, a circular dish of Russia sheet iron, about 12 in. wide, and 3 in. deep, with sloping sides. There should be a slight indentation all round where the sides join the bottom, so as to afford lodging for the gold grains, and the rustier it is the better. The Brazilian batea, made of hard wood in a solid piece, and hollowed out like a shallow funnel, is a superior implement when in capable hands. Another good substitute for this pan is a kind of magnified shovel, without handle, made of linden wood, and provided with a vertical wall on three sides. The wooden implements should be slightly charred on the surface to show up the gold grains, and should not have been used to hold mercury or amalgam. Absolute cleanliness is essential.

The sample to be treated, which should preferably be an exact quantity, say 5 to 25 lb., representing 100–500 assay tons, is crushed till it is fine enough to pass through a 60-mesh sieve, then moistened with water in the pan or other implement. The operator stands beside a tub filled with clean water, with strips across the top for the pan to rest on. Washing with a pan consists in gradually getting rid of the refuse matters by means of the water, the greater weight of the valuable portions enabling them to resist the tendency to be washed away. The greatest care must be taken that all parts of the mass be thoroughly washed by mixing up and squeezing in the hand, especially if any clay is present or other matter tending to increase the cohesiveness of the mass.

Successive small quantities of refuse are washed off and fresh portions of water taken on till the bulk is reduced to a small deposit of heavy matters, which may include magnetic iron, tin, bismuth, pyrites, platinum, and gold. The washing is done by means of a circular motion combined with a jerk or twist which helps the heavy particles to become dissociated from the light. A

*Auriferous Mineral*—continued.

sufficiency of water to keep the whole mass quite wet must be maintained throughout the operation. As the end approaches, a useful help is a bullock's horn with the small end plugged and then perforated so as to allow of a tiny and regular stream of water flowing out when the horn is filled by dipping it into the tub. By directing this little stream with care, the valuable particles can be collected in a small space by themselves. Then on being dried and weighed, they will give a very fair approximate idea of the value of the material treated. But a much more accurate estimate may be made by following the directions given by Brown in his 'Manual of Assaying':—

"If gold alone is obtained, that is, gold (or gold and silver) free from sulphurets, etc., it must be treated as an alloy, weighed, parted and weighed again, or cupelled with lead, weighed, parted and weighed; in both cases giving gold and silver.

"If the panning is not carried to such a point as to get rid of all the rock, the concentration is all scorified with test lead (or run down in a crucible), cupelled, parted and weighed. In the case of an ore supposed to carry auriferous sulphurets, it should be panned so far as can safely be done without losing metalliferous particles, and the concentration treated as above described.

"If the ore is quite poor, or a large quantity is desired to be worked, the panning can be carried on roughly, and the successive concentrations finally panned together.

"The results are based upon the amount of ore taken in the pan. If much of this work was to be done, a set of weights from 500 assay tons down (approximately accurate) would be very convenient and save calculation. The result would be as many times the number of oz. contained in the ore as the quantity of ore was more than 1 A.T.

"For example, the ore was supposed to be very poor and therefore 500 A. T. were taken. Bead weighed 50 mgrm.

$$\therefore 500 \text{ A. T.} : 1 \text{ A. T.} :: 50 \text{ mgrm.} : \frac{1}{10} \text{ mgrm.,}$$

or the ore ran  $\frac{1}{10}$  oz. Troy per ton.

"If 100 A. T. had been taken and the same weight bead obtained, we would have:

$$100 \text{ A. T.} : 1 \text{ A. T.} :: 50 \text{ mgrm.} : \frac{1}{2} \text{ mgrm.,}$$

or the ore would run  $\frac{1}{2}$  oz. Troy per ton.

"As an example of the calculation required without the large assay ton weights, I give the following:—

"Weight of panful of ore,  $2\frac{1}{4}$  kilo. = 2,250,000 mgrm.

"Weight of bead obtained, gold 20 mgrm., silver 50 mgrm.,

$$\text{then } \frac{2,250,000 \text{ mgrm.}}{20 \text{ mgrm}} :: \frac{29166}{x} \times = \frac{25}{100} = \frac{1}{4} \text{ oz. gold}$$

$$\text{and } \frac{2,250,000 \text{ mgrm.}}{50 \text{ mgrm.}} :: \frac{29166}{x} \times = \frac{64}{100} = \frac{8}{12.5} \text{ oz. silver.}$$

*Auriferous Mineral*—continued.

"The free gold can be separated from the sulphurets (if it be desired to determine how much of the gold is "free" and how much in "sulphurets") by washing in an amalgamated pan. Such a vessel may be simply made by bending a piece of thin silver-plated copper (about 6 in. by 12 in.) so as to form curved edges on three sides, the silvered sides in. The side not turned up is one of the narrow ends. A little mercury (free from gold and silver) will quickly amalgamate the interior, and if the ore is washed carefully over this, most of the free gold will become amalgamated and stick to the pan. A piece of chamois skin made into a rubber will push the gold, which can be seen as little specks of amalgam, to the open edge of the pan and into a crucible. The mercury can be driven from the gold by heat.

"No investigation has been made to determine if any silver is carried by the mercury to the assay from the pan, but if such be the fact, the result is still accurate for gold. If carefully performed, the results ought to be above the yield from a stamp-mill with amalgamated plates.

"A more common test than the above silver-plated amalgamated copper pan is, after having panned down, to drop a few globules of clean mercury into the pan and a little cyanide of potassium (to keep the mercury clean). Work up with a spatula till the mercury has taken up the free gold, then collect, and run off the mercury. Clean it and dissolve in nitric acid (for the gold only) or drive off the mercury in the muffle; weigh the residue of gold and silver, part, and weigh gold.

"The residue in the pan should then be assayed, and the gold and silver (actual weight) determined. Suppose

Original weight of ore	..	..	..	..	2½ kilo.
Gold and silver after retorting	..	..	..	..	35 mgrm.
Gold after parting	..	..	..	..	15 "
<hr/>					
Hence silver	..	..	..	..	20 mgrm.
Gold in sulphurets	..	..	..	..	50 "
Silver	"	..	..	..	90 "

"Then we have:

Free gold	$\frac{1.9}{100}$ oz. per ton of original ore.
Silver in free gold	$\frac{2.5}{100}$ oz. per ton of original ore.
Gold in sulphurets	$\frac{9.4}{100}$ oz. per ton of original ore.
Silver in sulphurets	$1\frac{1.6}{100}$ oz. per ton of original ore.
Total gold	$\frac{8.3}{100}$ oz. per ton of original ore.
Total silver	$1\frac{4.1}{100}$ oz. per ton of original ore.

"There is a certain loss in panning, hence the results are not analytically accurate, but are close indications of the practical result of the working of gold ores in a mill with copper plates."—*(Brown.)*

## ASSAYING.

### ASSAYING : *Auriferous Mineral. c. (Attwood.)*

In assaying the gold sand of the rivers, streams, and sea beaches of California, some difficulty is met with, as it contains a great amount of specular titanite iron, and is called "black sand" by the miners. Platinum and iridium are often found in the same sand. Following is a convenient method of testing these sands :—

Take 100 to 1000 gr. and attack with aqua regia in a flask ; cool for about 30 minutes or more ; dilute with water, and filter. If gold is present, it will now be held in solution in the filtrate. Remove the filter, and evaporate the filtrate to dryness ; then add a little hydrochloric acid, and redissolve the dry salt in warm water ; add to the solution so formed protosulphate of iron, which will throw down the gold in the form of a fine, dark precipitate. This precipitate is seldom pure, being mixed with oxides of iron, and must now be dried in the filter paper, and both burned over the lamp in a porcelain dish. Then mix the dried precipitate with three times its weight of lead ; fuse, scorify, and cupel. In case platinum, iridium, &c., are found associated with the gold, an exact amount of pure silver should be added before cupellation, and the gold button will be found pure.

### ASSAYING : *Auriferous Mineral. d. (Darton.)*

Small parts are chipped from all the sides of a mass of rock, amounting in all to about  $\frac{1}{2}$  oz. This is finely powdered in a steel mortar, and well mixed. About half of it is placed in a capacious test tube, and then partly filled with a solution made by dissolving 20 gr. of iodine and 30 gr. of iodide of potassium in about  $1\frac{1}{2}$  oz. water. The mixture thus formed is thoroughly agitated by shaking and warming ; then, after all particles have subsided, dip a piece of pure white filter paper in it, allow it to remain for a moment, then let it drain, and dry it over the spirit lamp. It is then placed upon a piece of platina foil held in pincers, and this heated to redness over the flame ; the paper is speedily consumed ; and after heating further, to burn off all carbon, it is allowed to cool, and then examined. If at all purple, gold is present in the ore, and the relative amount may be approximately deduced, as much, fair, little, or none. This method takes but little time and is very trustworthy.

### ASSAYING : *Auriferous Mineral. e.*

The following simple method for the detection of gold in quartz, pyrites, &c., is an adaptation of the well known amalgamation process, and serves to detect very minute traces of gold. Place the finely powdered and roasted mineral in a test tube ; add water and a single drop of mercury ; close the test tube with the thumb, and shake thoroughly and for some time. Decant the water, add more, and decant repeatedly, thus washing the drop of mercury until it

*Auriferous Mineral*—continued.

is perfectly clean. The drop of mercury contains any gold that may have been present. It is therefore placed in a small porcelain capsule, and heated until the mercury is volatilised and the residue of gold is left in the bottom of the capsule. This residue may be tested either by dissolving in aqua regia and obtaining the purple of Cassius with protochloride of tin, or by taking up with a fragment of moist filter paper, and then fusing to a globule on charcoal in the blowpipe flame.

ASSAYING: *Auriferous Mineral.* f.

The mechanical assay of auriferous sands or stamped ore, based on common pan-washing, is of the utmost practical value to the miner as a working test. It does not give all the gold in the rock, as shown by a careful fire assay, but what is of equal importance to the mine owner, mill man, and practical miner, it gives what he can reasonably expect to save in a good quartz mill. It is really milling on a small scale. It is generally very correct and reliable, if a quantity of material be sampled. The only operation which requires much skill is the washing, generally well understood by those who are most likely to avail themselves of the instruction. These rules apply equally to placer gravels. Take a quantity of the ore—the larger the better—and spall it into pieces of less size than an egg. Spread on a good floor and, with a shovel, mix very thoroughly; then shovel into three piles, placing one shovelful upon each in succession, until all is disposed of. Two of the piles may then be put into bags. The remaining pile is spread out on the floor, mixed as before, and shovelled in the same manner into three piles. This is repeated according to the quantity sampled, until the last pile does not contain more than 30 lb. of ore. As the quantity on the floor becomes smaller, the lumps must be broken finer until the last, when they should not exceed 1 in. in diameter. What remains is removed to an iron slab and, by the aid of an iron ring and hammer, reduced to the size of peas. The whole 30 lb. is then spread out, and after careful mixing, portions are lifted with a flat knife—taking up the fine dust with the larger fragments—until about 10 lb. have been gathered. This quantity is then ground down fine with the muller, and passed through a 40-mesh sieve. If the rock is rich, the last portion will be found to contain some free gold in flattened discs, which will not pass the sieve. These must be placed with the pulverised ore, and the whole thoroughly mixed, if the quantity is small; but if large, must be treated separately, and the amount of gold calculated into the whole 10 lb., and noted when the final calculation is made. From the thoroughly mixed sample, 2 kilo. (2000 grammes) must be carefully weighed out. This is placed in a pan, or, better, in a batea, and carefully washed down until the gold begins to appear. Clean water is then used, and when the pan and the small residue are



*Auriferous Mineral—continued.*

clean, most of the water is poured off and a globule of pure mercury (which must be free from gold) is dropped in—a piece of cyanide of potassium is also placed with it. As the cyanide begins to dissolve, a rotary motion is imparted to the dish—best done by holding the arms stiff and moving the body. As the mercury rolls over and ploughs through the sand, under the influence of the cyanide, it will collect together all the particles of free gold. When it is certain that all is collected, the mercury may be carefully transferred to a small porcelain cup or test tube, and boiled with strong nitric acid, which must be pure. When the mercury is all dissolved, the acid is poured off, more nitric acid is applied cold, and rejected, and the gold is then washed with distilled water and dried. The object of washing with acid the second time is to remove any nitrate of mercury which might remain with the gold, and which is immediately precipitated if water is first used. The resulting gold is not pure, but has the composition of the natural alloy. Before accurate value calculations can be made, it will be necessary to render the gold pure and weigh it carefully. To purify the gold, it must be melted with silver, rolled out, or hammered thin, boiled twice with nitric acid, washed, dried, and heated to redness. The method of calculating this assay is very simple. It will be observed that 2000 grammes were weighed out. Let the 2000 grammes represent a ton of 2000 lb., then each gramme will be equivalent to 1 lb. avoirdupois, or one 2000th part of the whole, and the decimals of a gramme the decimals of a pound. Suppose the ore yielded, by the assay just described, fine gold weighing .072 gramme, it must be quite evident that a ton of the ore would yield the same decimal of 1 lb. Now it is only necessary to multiply the value by the weight of gold obtained in grammes and decimals to find the value of the gold in a ton of ore. Care must be taken in this assay to keep the cyanide solution rather weak, as gold is somewhat soluble in strong solution of cyanide of potassium, and to remember that cyanide is deadly poison, which should be handled with great care.

*ASSAYING: Auriferous Mineral. g.*

Take (1) 200 gr. ore, 500 gr. litharge, 6 gr. lampblack, 500 gr. carbonate of soda; or (2) 200 gr. ore, 200 gr. red lead, 150 gr. carbonate of soda, 8 gr. charcoal, 6 gr. borax; mix and put into a warmed crucible, and cover with  $\frac{1}{2}$  in. of common salt; fuse in a hot fire 30 minutes; cool, and break the pot; clean the button with a small hammer. If the quartz is very pyritous, take 1000 gr. and calxine "dead" without clotting. Add 500 gr. red lead, 35 gr. charcoal, 400 gr. borax, 400 gr. carbonate of soda. Cover with salt and proceed as above. In each case cupel the button. As the bone ash of which the cupel is made can absorb its own weight of metallic oxides, the cupel chosen should always exceed the weight

*Auriferous Mineral—continued.*

of the button to be operated on, so as to have a margin. Boil the gold prill, obtained from cupelling, in nitric acid, which dissolves the silver and leaves the gold pure. These formulæ are open to modification by the operator according to the apparent richness or poverty of the ore to be treated, and the presence and character of the basic impurities. In case there are oxides, a reducing agent is required; if sulphides, an oxidising agent. As a rule, employ a weight of litharge *twice* that of the ore, and of carbonate of soda the same as the ore. These reagents are added to control the size of the lead button, and to obtain one of a suitable size for cupelling. *See also p. 345.*

*ASSAYING: Auriferous Metal.*

Select from the samples several pieces, to represent as fair an average as possible, and divide each of them with the cold-chisel. Then with each piece, using the fresh cut edges, make parallel marks on a touchstone, and lay the pieces of gold on the table in the same succession. Wet the gold streaks on the stone with nitric acid, using a glass rod or the stopper of a coin test. If no reaction takes place, and the streaks look as bright and metallic as before, the gold is at least 640 fine, and probably finer even than that; wipe the stone gently with a piece of soft rag, and apply test acid in the same manner; if there is still no reaction, the gold is finer than 750; if any action is observed, the fineness is between the two. Test acid is made by mixing 98 parts of pure nitric acid of 37° Beaumé with two parts of hydrochloric acid of 21° B., and 25 parts of distilled water by measure. If the golden streaks are not acted on by nitric acid, or by the test acid, take a touch needle marked 700, and make a similar streak on the stone below that made with the samples. Compare the colour, and then progress with other needles, both copper and silver, using a higher mark each time, until a colour corresponds to that of the samples; an approximate knowledge of the quality of the gold will thus be obtained. But, should nitric acid cause any change in the appearance of the streaks on the touchstone, and the preliminary test in the watch glass indicated copper, try the copper needles and apply in the reverse order until you hit the colour, and find a needle, the streak of which is acted upon in a similar manner by nitric acid. If silver was indicated, use the silver needles. Considerable practice and a good eye are required to obtain accurate results with the touchstone, but this is soon acquired. Gold dust and retorted amalgam should be examined for mercury. This is done by putting a small fragment into a glass tube, closed at one end, observing that it falls quite to the bottom. Place the end of the finger loosely over the opening, and heat the closed end of the tube where the piece of gold lies, in the flame of the spirit lamp. If mercury is present, a bright ring will form in the tube above the

*Auriferous Metal*—continued.

**assay.** Upon examination with a magnifying glass, the ring will be found to be minute globules of mercury. To be certain, make a scratch with a file below the ring, and break off the closed end of the tube. Place the end of the now open tube into a few drops of water in a watch glass, and then, with a feather, or small stick, the sublimate may be brushed into the water, and by gently shaking, be caused to coalesce into a single globule, in which form it cannot be mistaken for any other substance.

ASSAYING : *Bullion.*

Any person skilled in the use of the blowpipe and possessing a good balance can make accurate assays of bullion or gold dust ; but the results will be only approximate unless the whole lot is melted into a bar. As this is not always convenient, the following plan may be adopted. Pour the gold dust out on a large and perfectly clean sheet of paper, and with the ends of the fingers mix it thoroughly, occasionally lifting the edge of the paper to throw it together, and again mixing to ensure uniformity ; then, from various parts, lift small portions, until more than 1 oz. is collected—this is best done with a flat knife, or by pinching with the thumb and forefinger—from this, weigh out accurately 1 oz. troy ; place this in a small crucible, add a little borax, carbonate of soda, and nitrate of potash, and melt the whole together—this may easily be done in a blacksmiths' forge or in a coal stove ; when perfectly melted, set the crucible aside, and when cold, break and remove the gold button ; this must be freed from clay and slag by light blows of the hammer on its edges, and subsequent washing. When perfectly clean and dry, weigh again. The loss is water, iron, sand, mercury, and other impurities, which may be assumed to be the average of the entire lot. Cut off a small portion from each side with a cold-chisel, wrap the pieces in paper to prevent them from flying, and hammer down on the anvil until thin enough to cut with scissors ; place upon charcoal, and heat with the blowpipe flame until the paper is burned away, taking care not to melt the gold. Cut with a pair of shears sufficient to weigh exactly  $\frac{1}{10}$  gramme, or 100 milligrammes ; a portion should be taken from each of the pieces. The weighing must be conducted with the greatest accuracy, for the success of the assay depends upon precise manipulation. Blowpipe cupels are made of the finest washed bone-ash, formed in a cupel mould of boxwood or ebony, hammered with sufficient force to make them compact, and well dried. They are about  $\frac{1}{4}$  in. diameter, and less than that in height. For convenience, they may be supported in a ring of platinum wire, in a handle of cork, or fused into a glass rod. Place the assay in the centre of a piece of lead foil about  $\frac{1}{4}$  in. square ; fold the lead over the gold, and with the fingers carefully form it into a ball and set it aside.

*Bullion—continued.*

Prepare two assays like this. Take the cupel support in the left hand, and, having lighted a spirit lamp, lift one of the cupels by placing the end of the forefinger in the concave part, and holding it lightly with the thumb, place it in the loop of wire. Heat the cupel by urging the whole of the flame upon it, producing in doing so a roaring sound. This is best done by holding the point of the blowpipe outside the flame. When the cupel is hot enough, which is known by its becoming white after first blackening, lift with the pliers one of the assays, and place it in the centre of the cupel. A steadily-pointed blue flame must then be directed upon the assay until it melts and begins to oxidise, when the flame is changed to a roaring blast, and the cupel is moved farther from the lamp. Cupellation goes on rapidly if the flame is directed against the cupel beyond the assay, and not directly upon it, and if the cupel is kept cool—that is to say, at the lowest temperature at which the lead can be kept fluid. It will be found advantageous to discontinue the flame for an instant occasionally, and to direct it by short puffs at times. The exact point can only be attained by removing the cupel from the lamp, and returning it gradually, as may be required. As the cupellation goes on, the bead becomes more spherical; little patches of lead oxide form and pass to the cupel, becoming thinner, until at last the gold bead can be seen through the slight film of oxide. When nearly finished, the molten gold spits up towards the flame. At last, at the proper moment, learned only by practice, an instant cessation of the blast causes a flash, and a bright yellow golden bead remains on the cupel. When cold, the bead is removed from the cupel with pliers, and placed flat side down on a clean piece of paper. It is then grasped with a large pair of pincers and squeezed by a strong pressure. This generally removes all adhering bone-ash, and renders the button fit for weighing. To make sure, turn it over, examine with the magnifying glass, and brush with a small short-bristle brush. If anything should be found attached to it, a squeeze at right angles with the first will generally remove it. Place the button in the pan of the balance and weigh it carefully. Its weight in milligrammes is the total fineness in hundredths. For instance, 74 milligrammes would be 740 fine. With a delicate balance, thousandths can be weighed, each tenth of a milligramme being .001.

The button will probably contain silver. To ascertain the fineness of gold, it must be subjected to a second process. The weight of the bead being noted, a cavity is made in a piece of charcoal, held by means of a proper support. In the cavity is placed the gold button, with four or five times its volume of pure silver, and both metals are melted together before a strong blowpipe flame. The alloy must be thoroughly fused. When cool, it is wrapped in paper, hammered flat, heated red hot to burn away the paper, cleaned with the stiff brush, placed in a test tube with nitric acid,

*Bullion—continued.*

and boiled over a spirit lamp until no more red fumes are given off. A black powder, which is the gold, will remain. The tube is then filled up with distilled water, which is poured off carefully, so as not to permit any of the finely divided gold to pass away with it. This must be repeated, and the tube filled full for the third time with distilled water. A porcelain cup is then placed over the tube, like a cap, and both are inverted together. The gold falls to the bottom of the cup, and the tube is carefully removed. The water is then poured from the gold in the cup, which is first subjected to a gentle heat, and then made red-hot by the aid of the blow-pipe. During the process the cup may be held, by the aid of pincers, over the flame of the spirit lamp, which is urged upward against it from below. When the gold has assumed its metallic colour, the operation is finished. When cold, the gold is brushed into the pan of the balance, and its weight in tenths of a milligramme is noted. The results may be written as follows: Suppose the weight of the cupelled button, in milligrammes, to be 74.4, the total fineness will be 744; weight of gold powder,  $69.2 = 692$ ; fineness of silver, 52. Or, fineness of gold, 692; fineness of silver, 52; total fineness, 744.

It is important in estimating the value of purchased gold dust, to carefully examine, to see if there is any counterfeit, or, as it is called, "bogus" dust present. If all from the same locality, the dust will have a uniform colour. Any suspicious-looking pieces should be set aside and cut with a cold chisel while lying on a small anvil. A fair sample of the whole lot of gold dust under examination should then be placed in an evaporating dish, the suspected pieces being placed on top, and nitric acid poured over them. If any reaction takes place, such as effervescence, or evolution of red fumes, or if the acid becomes coloured, there is foreign matter present, and should this be the case, adulteration or counterfeit gold dust may be suspected. Place two watch glasses, one on a piece of white paper and the other on black, or some dark colour; then, with a glass rod, convey a few drops of the acid from the dish to each. To the white add a drop or two of ammonia until it smells strongly ammoniacal; a blue colour indicates copper. To the other add hydrochloric acid in the same manner. If a white, curdy precipitate forms, which does not dissolve upon the addition of water, silver is being dissolved from the gold dust in the evaporating dish. If the dust is of very low grade, these metals may dissolve in very small quantities. But such gold dust would be easily detected by its inferior colour and appearance. If no action is observed, even after heating the dish, there is no counterfeit present. Counterfeit gold dust is sometimes heavily coated with pure gold (by the galvanic process) so as to protect the base alloy from the action of nitric acid, hence the necessity of cutting all suspected pieces before submitting to the action of the acid. To remove the acid from the gold, wash with water thoroughly, and dry over the spirit lamp.

Table 137.—*Sulphurets, identifying. (Brown.)*

Kind of Sulphuret.	Before Heating.		During Rapid Heating.			After Heating (when cold).		
	Colour of Ore.	Character.	Fumes.		Other Characteristics.	Colour of Ore.	Character.	Composition.
			Character.	Odour.				
1. Blende ..	Brown, shading to green, red, and yellow	Shining	Very slight	None	Glow yellow-green when hot	Buff or yellowish	Dead, dull	Oxide of zinc.
2. Manganblende ..	Green, greenish grey	Dull	Slight	None	Glow	Brown	Dead, dull	Brown oxide of manganese.
3. Pyrite ..	Greenish or brownish black	Shining, not magnetic	Slight	None	Glow	Red to black, many shades	Dead, dull	Red oxide of iron.
4. Pyrrhotite ..	Grey black	Shining, is magnetic	Slight	None	Glow	Red to black, many shades	Dead, dull	Red oxide of iron.
5. Arsenopyrite ..	Grey black	Shining	White, very thick	Like garlic	Glow, swells	Red to black, many shades	Dead, dull	Red oxide of iron.
6. Chalcocite ..	Grey	Shining	Slight	None	Glow, fuses	Grey	Shining, powder red	Oxide of copper.
7. Chalcopyrite ..	Green black	Shining	Some fumes	None	Glow, fuses	Grey	Shining, powder grey	Oxides of iron and copper.
8. Bornite ..	Dark green	Shining	Some fumes	None	Glow	Grey	Shining, powder brown,	Oxides of iron and copper.
9. Tetrahedrite ..	Dark grey	Shining	Much	Garlic odour sometimes	Glow, swells, fuses	Grey	Shining	Mixed oxides.
10. Stibnite ..	Lead grey	Shining	White fumes	None	Glow, swells, boils	Grey green	A thin film of shining mass	Oxide of antimony.
11. Galenite ..	Grey	Very decided shine	Fumes considerably	None	Fuses	Yellow green	Shining	Oxide of lead.
12. Argentite ..	Grey black, pink and brown shades	Very little shine	Some	None	Fuses	Grey	Somewhat shining	Oxide of silver somewhat reduced.

(Each sulphuret will give a little odour of sulphur, but it is not to be confounded with the odour of arsenic.)

Table 138.—*Reducing Agents.*

1 part of the undermentioned will reduce of metallic lead :—

	Parts.		Parts.
Argol, crude ..	5½–8½	Flour, wheat .. ..	15
Charcoal, ordinary	22–30	Gum arabic, powdered	11
Coke, powdered ..	24	Starch, corn .. ..	11½–13
hard coal	25	"    laundry .. ..	11½–13
soft "	22	Sugar, white, powdered	14½
Cream of tartar .			

Table 139.—*Sulphurets, oxidising.* (Brown.)

Kind of Sulphuret.	Parts of litharge required to completely oxidise 1 part of the sulphuret.	Parts of metallic lead reduced by 1 part of the sulphuret.	Percentage of the sulphuret which with charges of 1 A.T. will reduce a lead button of about 15 grm.	Parts of nitre required to completely oxidise 1 part of the sulphuret.
1. Zinc blende .. .. .	25	6·5	7·7	—
2. Manganblende .. ..	30	6·7	7·5	—
3. Iron pyrites .. .. .	50	8·6	5·8	2·5
4. Arsenopyrite .. .. .	40	7·3	6·5	—
5. Copper pyrites .. ..	30	7·2	7	—
6. Copper glance .. ..	25	3·8	13	—
7. Grey copper .. .. .	35	6	8	—
8. Grey antimony .. ..	25	5·7	9	—
9. Galena .. .. .	1·8	2·8*	18	·66

\* All the lead of the galena and litharge.

Table 140.—Charges for Gold and Silver Ores.

Ingredients.										Assay tons.	Grammes.	Troy gr.
1. Antimonial and arsenical ores. (Brown.)												
Ore	..	..	..	..	..	..	..	..	..	$\frac{1}{8}$	5	96
Granulated lead	..	..	..	..	..	..	..	..	..	$\frac{1}{4}$	120	1920
Borax glass	..	..	..	..	..	..	..	..	..	—	$1\frac{1}{2}$	23
2. Carbonate ores. (Brown.)												
Ore	..	..	..	..	..	..	..	..	..	$\frac{1}{8}$	5	96
Granulated lead	..	..	..	..	..	..	..	..	..	$\frac{1}{2}$	60	960
Borax glass	..	..	..	..	..	..	..	..	..	—	$\frac{1}{2}$	$7\frac{1}{2}$
3. Chloride ores. (Brown.)												
Ore	..	..	..	..	..	..	..	..	..	$\frac{1}{2}$	5	96
Granulated lead	..	..	..	..	..	..	..	..	..	$1\frac{1}{2}$	33	576
Borax glass	..	..	..	..	..	..	..	..	..	—	$\frac{1}{2}$	5
4. Common ores not containing much lead or copper. (Brown.)												
Ore	..	..	..	..	..	..	..	..	..	$\frac{1}{10}$	$2\frac{1}{2}$	48
Granulated lead	..	..	..	..	..	..	..	..	..	$2\frac{1}{2}$	75	1200
Borax glass	..	..	..	..	..	..	..	..	..	—	$\frac{1}{2}$	4
5. Common ores. (Mitchell.)												
Ore	..	..	..	..	..	..	..	..	..	1	30	480
Soda	..	..	..	..	..	..	..	..	..	1	30	480
Litharge	..	..	..	..	..	..	..	..	..	5	150	2400
Borax glass	..	..	..	..	..	..	..	..	..	1	30	480
Salt cover.												
6. Common ores. (Brown.)												
Ore	..	..	..	..	..	..	..	..	..	1	30	480
Soda	..	..	..	..	..	..	..	..	..	1	30	480
Litharge	..	..	..	..	..	..	..	..	..	1.65	50	800
Salt cover.												
7. Common ores. (Aaron.)												
Ore	..	..	..	..	..	..	..	..	..	1	30	480
Soda	..	..	..	..	..	..	..	..	..	3	90	1440
Litharge	..	..	..	..	..	..	..	..	..	1	30	480
Borax	..	..	..	..	..	..	..	..	..	$\frac{1}{2}$	15	240
Sulphur	..	..	..	..	..	..	..	..	..	$\frac{1}{10}$	3	48
Flour	..	..	..	..	..	..	..	..	..	$\frac{1}{10}$	3	48
Iron, 3 nails.												
Glass.												
Salt cover.												
8. Common ores, not pyritic. (Aaron.)												
Ore	..	..	..	..	..	..	..	..	..	1	30	480
Soda	..	..	..	..	..	..	..	..	..	1	30	480
Litharge	..	..	..	..	..	..	..	..	..	2	60	960
Borax, dried	..	..	..	..	..	..	..	..	..	1	30	480
Flour	..	..	..	..	..	..	..	..	..	—	1	16
Salt cover.												



Table 140—continued.

Ingredients.		Assay tons.	Grammes.	Troy gr.
9. Common ores, not pyritic. (Brown.)				
Ore	.. .. .	1	30	480
Soda bicarbonate	.. .. .	1½	45	720
Potash carbonate	.. .. .	½	15	240
Litharge	.. .. .	1½	45	720
Silica	.. .. .	1	30	480
Borax glass	.. .. .	½	15	240
Charcoal	.. .. .	—	½	9½
Salt cover; ¼ hour in fire.				
10. Copper glance or pyrites. (Brown.)				
Ore	.. .. .	⅓	2½	48
Granulated lead	.. .. .	2½	75	1200
Borax glass	.. .. .	—	½	3
11. Copper matte. (Brown.)				
Matte	.. .. .	⅓	2½	48
Granulated lead	.. .. .	3	90	1440
Powdered silica	.. .. .	⅓	1½	24
12. Copper, grey ores. (Brown.)				
Ore	.. .. .	⅓	2½	48
Granulated lead	.. .. .	2	60	960
Borax glass	.. .. .	—	½	5
13. Iron sulphides. (Brown.)				
Ore	.. .. .	½	7½	120
Granulated lead	.. .. .	2½	75	1200
Borax glass	.. .. .	—	½	3
14. Iron oxides. (Brown.)				
Ore	.. .. .	⅓	5	96
Granulated lead	.. .. .	1½	45	720
Silica	.. .. .	—	1	15½
Borax glass	.. .. .	—	½	5½
15. Lead sulphide. (Brown.)				
Ore	.. .. .	½	15	240
Granulated lead	.. .. .	1½	45	720
Borax glass	.. .. .	—	⅓	1½
16. Native gold or silver, or very rich ores. (Brown.)				
Ore	.. .. .	⅓	2½	48
Granulated lead	.. .. .	1½	45	720
Borax glass	.. .. .	—	½	4
17. Tellurides. (Brown.)				
Ore	.. .. .	⅓	2½	48
Granulated lead	.. .. .	2	60	960
Litharge	.. .. .	⅓	2½	48
Borax glass	.. .. .	—	½	4
18. Zinc blende. (Brown.)				
Ore	.. .. .	½	5	96
Granulated lead	.. .. .	3	90	1440
Borax glass	.. .. .	—	½	6

Table 141.—*Assay Ton Equivalents in Grammes, Troy Grains, and Troy Ounces. (Brown.)*

Based on 1 grm. = 15.43235 Troy gr.; hence 1 assay ton or  
 29.166 grm. =  $15.43235 \times 29.166 = 450.09992$  Troy gr.

A. T.	Grm.	Troy gr.	Troy oz.	A. T.	Grm.	Troy gr.	Troy oz.
0.05	1.458	22.504	..	2.50	72.916	1125.249	2.344
0.10	2.916	45.009	..	2.55	74.374	1147.754	2.391
0.15	4.374	67.514	..	2.60	75.833	1170.259	2.438
0.20	5.833	90.019	..	2.65	77.291	1192.764	2.485
0.25	7.291	112.524	..	2.70	78.749	1215.269	2.531
0.30	8.749	135.029	..	2.75	80.208	1237.774	2.579
0.35	10.208	157.534	..	2.80	81.666	1260.279	2.626
0.40	11.666	180.039	..	2.85	83.124	1282.784	2.672
0.45	13.124	202.544	..	2.90	84.583	1305.289	2.719
0.50	14.583	225.049	..	2.95	86.041	1327.794	2.766
0.55	16.041	247.554	..	3.00	87.499	1350.299	2.813
0.60	17.499	270.059	..	3.05	88.958	1372.804	2.860
0.65	18.958	292.564	..	3.10	90.416	1395.309	2.905
0.70	20.416	315.069	..	3.15	91.874	1417.814	2.954
0.75	21.874	337.574	..	3.20	93.333	1440.319	3.001
0.80	23.333	360.079	..	3.25	94.791	1462.824	3.048
0.85	24.791	382.584	..	3.30	96.249	1485.329	3.094
0.90	26.249	405.089	..	3.35	97.708	1507.834	3.141
0.95	27.708	427.594	..	3.40	99.166	1530.339	3.188
1.00	29.166	450.099	..	3.45	100.624	1552.844	3.235
1.05	30.624	472.604	..	3.50	102.083	1575.349	3.282
1.10	32.083	495.109	1.032	3.55	103.541	1597.854	3.329
1.15	33.541	517.614	1.078	3.60	104.999	1620.359	3.376
1.20	34.999	540.119	1.125	3.65	106.458	1642.864	3.423
1.25	36.458	562.624	1.173	3.70	107.916	1665.369	3.470
1.30	37.916	585.129	1.219	3.75	109.374	1687.874	3.516
1.35	39.374	607.634	1.266	3.80	110.833	1710.379	3.563
1.40	40.833	630.139	1.313	3.85	112.291	1732.884	3.610
1.45	42.291	652.644	1.360	3.90	113.749	1755.389	3.657
1.50	43.749	675.149	1.407	3.95	115.208	1777.894	3.704
1.55	45.208	697.654	1.453	4.00	116.666	1800.399	3.751
1.60	46.666	720.159	1.500	4.05	118.124	1822.904	3.798
1.65	48.124	742.664	1.547	4.10	119.583	1845.409	3.845
1.70	49.583	765.169	1.594	4.15	121.041	1867.914	3.891
1.75	51.041	787.674	1.641	4.20	122.499	1890.419	3.938
1.80	52.499	810.179	1.667	4.25	123.958	1912.924	3.985
1.85	53.958	832.684	1.735	4.30	125.416	1935.429	4.032
1.90	55.416	855.189	1.782	4.35	126.874	1957.934	4.079
1.95	56.874	877.694	1.829	4.40	128.333	1980.439	4.126
2.00	58.333	900.199	1.875	4.45	129.791	2002.944	4.173
2.05	59.791	922.704	1.922	4.50	131.249	2025.449	4.220
2.10	61.249	945.209	1.969	4.55	132.708	2047.954	4.267
2.15	62.708	967.714	2.016	4.60	134.166	2070.459	4.313
2.20	64.166	990.219	2.063	4.65	135.624	2092.964	4.360
2.25	65.624	1012.724	2.110	4.70	137.083	2115.469	4.407
2.30	67.083	1035.229	2.157	4.75	138.541	2137.974	4.454
2.35	68.541	1057.734	2.204	4.80	139.999	2160.479	4.500
2.40	69.999	1080.239	2.250	4.85	141.458	2182.984	4.548
2.45	71.458	1102.744	2.297	4.90	142.916	2205.489	4.595

Table 141—continued.

A. T.	Grm.	Troy gr.	Troy oz.	A. T.	Grm.	Troy gr.	Troy oz.
4.95	144.374	2227.994	4.642	7.50	218.749	3375.729	7.033
5.00	145.833	2250.499	4.689	7.55	220.208	3398.234	7.080
5.05	147.291	2273.004	4.735	7.60	221.666	3420.739	7.127
5.10	148.749	2295.509	4.782	7.65	223.124	3443.244	7.173
5.15	150.208	2318.014	4.829	7.70	224.583	3465.749	7.220
5.20	151.666	2340.519	4.876	7.75	226.041	3488.254	7.267
5.25	153.124	2363.024	4.923	7.80	227.499	3510.759	7.314
5.30	154.583	2385.529	4.970	7.85	228.958	3533.264	7.361
5.35	156.041	2408.034	5.017	7.90	230.416	3555.769	7.408
5.40	157.499	2430.539	5.064	7.95	231.874	3578.274	7.455
5.45	158.958	2453.044	5.111	8.00	233.333	3600.779	7.502
5.50	160.416	2475.549	5.157	8.05	234.791	3623.284	7.549
5.55	161.874	2498.054	5.204	8.10	236.249	3645.789	7.595
5.60	163.333	2520.559	5.251	8.15	237.708	3668.294	7.642
5.65	164.791	2543.064	5.298	8.20	239.166	3690.799	7.689
5.70	166.249	2565.569	5.345	8.25	240.624	3713.304	7.736
5.75	167.708	2588.074	5.392	8.30	242.083	3735.809	7.783
5.80	169.166	2610.579	5.439	8.35	243.541	3758.314	7.830
5.85	170.624	2633.084	5.486	8.40	244.999	3780.819	7.877
5.90	172.083	2655.589	5.532	8.45	246.458	3803.324	7.924
5.95	173.541	2678.094	5.579	8.50	247.916	3825.829	7.970
6.00	174.999	2700.599	5.626	8.55	249.374	3848.334	8.017
6.05	176.458	2723.084	5.673	8.60	250.833	3870.839	8.064
6.10	177.916	2745.589	5.720	8.65	252.291	3893.344	8.111
6.15	179.374	2768.094	5.767	8.70	253.749	3915.849	8.158
6.20	180.833	2790.599	5.814	8.75	255.208	3938.354	8.205
6.25	182.291	2813.104	5.861	8.80	256.666	3960.859	8.252
6.30	183.749	2835.609	5.908	8.85	258.124	3983.364	8.299
6.35	185.208	2858.114	5.954	8.90	259.583	4005.869	8.346
6.40	186.666	2880.619	6.001	8.95	261.041	4028.374	8.392
6.45	188.124	2903.124	6.048	9.00	262.499	4050.879	8.439
6.50	189.583	2925.629	6.095	9.05	263.958	4073.384	8.486
6.55	191.041	2948.134	6.142	9.10	265.416	4095.889	8.533
6.60	192.499	2970.639	6.189	9.15	266.874	4118.394	8.580
6.65	193.958	2993.144	6.236	9.20	268.333	4140.899	8.627
6.70	195.416	3015.649	6.283	9.25	269.791	4163.404	8.674
6.75	196.874	3038.154	6.329	9.30	271.249	4185.909	8.721
6.80	198.333	3060.659	6.376	9.35	272.708	4208.414	8.768
6.85	199.791	3083.164	6.423	9.40	274.166	4230.919	8.814
6.90	201.249	3105.669	6.470	9.45	275.624	4253.424	8.861
6.95	202.708	3128.174	6.517	9.50	277.083	4275.929	8.908
7.00	204.166	3150.679	6.564	9.55	278.541	4298.434	8.955
7.05	205.624	3173.184	6.611	9.60	279.999	4320.939	9.002
7.10	207.083	3195.689	6.658	9.65	281.458	4343.444	9.049
7.15	208.541	3218.194	6.705	9.70	282.916	4365.949	9.096
7.20	209.999	3240.699	6.751	9.75	284.374	4388.454	9.143
7.25	211.458	3263.204	6.798	9.80	285.833	4410.959	9.189
7.30	212.916	3285.709	6.845	9.85	287.291	4433.464	9.236
7.35	214.374	3308.214	6.892	9.90	288.749	4455.969	9.283
7.40	215.833	3330.719	6.939	9.95	290.208	4478.474	9.330
7.45	217.291	3353.224	6.986	10.00	291.666	4500.979	9.377

By using this system, calculation of gold and silver values of an ore becomes very simple.

*Assay Ton equivalents—continued.*

<i>Ex. 1.</i> —Amount of ore taken .. .. .	$\frac{1}{5}$ A. T.
Amount of test-lead used .. .. .	$1\frac{1}{2}$ MGRM. "
Weight of gold and silver bead .. .. .	8.50
"    silver in $1\frac{1}{2}$ A. T. lead .. .. .	.25
True weight of gold and silver bead .. .. .	8.25
Weight of gold in the bead .. .. .	1.10
Weight of silver in the bead .. .. .	7.15

$7.15 \times 5 = 35.75 = 35\frac{3}{4}$  mgrm. =  $35\frac{3}{4}$  oz. silver per ton of ore.

$1.10 \times 5 = 5.5 = 5\frac{1}{2}$  mgrm. =  $5\frac{1}{2}$  oz. gold per ton of ore.

<i>Ex. 2.</i> —Amount of ore taken .. .. .	$\frac{1}{2}$ A. T.
Amount of test-lead used .. .. .	1 MGRM. "
Weight of gold and silver bead .. .. .	231.90
Weight of silver in test-lead .. .. .	0.00
True weight of gold and silver bead .. .. .	231.90
Weight of gold, "faint trace" .. .. .	0.00
Weight of silver in the bead .. .. .	231.90

$231.9 \times 2 = 463.8 = 463\frac{8}{10}$  mgrm. =  $463\frac{8}{10}$  oz. silver per ton of ore. (Brown.)

*Copper.*

(a) *Native Ore.*—Into a crucible put—

	Grammes.	Troy gr.
Ore .. .. .	10	160
Soda bicarbonate .. .. .	20	320
Potash carbonate .. .. .	5	80
Borax glass .. .. .	1	16

Cover with  $\frac{1}{2}$ -in. salt and 1 in. wood charcoal; heat intensely for 20–30 minutes; cool, break crucible, clean button from slag; divide weight of button by 10 gm. or 160 gr. and multiply by 100 for percentage of copper.

(b) *Oxides and Carbonates, free from sulphur.*—Into a chalk-lined crucible put—

	Grammes.	Troy gr.
Ore .. .. .	10	160
Black flux substitute (10 parts soda bicarbonate, 3 wheat flour) .. .. .	30	480
Borax glass .. .. .	5	80
Argol .. .. .	2	32

Cover with salt and charcoal as (a); heat gradually 20 minutes, and to white heat for 40; remove, tap, and cool.

*Copper—continued.*

(c) *Sulphides, containing antimony, arsenic, lead, mercury, zinc, &c.*—In order to concentrate all the copper into a matte, and eliminate lime or baryta gangues, mix—

	Grammes.	Troy gr.
Ore, according to richness .. .. .	10-30	160-180
Borax glass .. .. .	8-24	128-384

Add a couple of nails if lead is present; also 2-6 grm. (32-96 gr.) iron pyrites free from copper, unless present in the ore to some extent. Use a salt cover; fuse in hot fire; remove nails when finished, cool, break away slag.

Next roast the matte with extreme care, using coke and no silica, so as to expel sulphur and volatile metals, and convert copper into an oxide.

To reduce the oxide to metal, mix—

	Grammes.	Troy gr.
Roasted ore .. .. .	30	480
Black flux substitute (10 parts soda bicarbonate, 3 wheat flour) .. .. .	90	1440
Borax glass .. .. .	15	240
Lime glass .. .. .	7½	120
Red oxide of iron .. .. .	3	48

introducing first into the crucible a mixture of the ore, iron oxide, and one-third the black flux substitute; when settled down, add the rest of the black flux substitute, borax glass, lime glass, and salt cover successively, laying on all a piece of coal, the size of a hazel nut. Gradually raise heat to intensity; remove, cool, detach button, weigh and estimate if malleable and apparently pure.

If not pure, heat two large cupels in a muffle; place in each 3 grm. (48 gr.) pure lead, and close muffle; when lead is melted, put the impure button (a) in one cupel and a piece of pure copper (b) of same weight in the other. On their "brightening," cover cupels with coke or coal-dust, take out and cool in water. Add loss sustained by b to both, and compare.

(d) *All Ores, or Alloys.*—This is an electrolytic (wet) process, preferable to all the others. Place 1 grm. of rich ore (over 20 per cent.) or 5 grm. of poor (under 20 per cent.), very finely ground, in a casserole, cover with watch-glass, and add 10 c.c. pure concentrated nitric acid from a pipette. Heat in sand bath for some time; when cold add 5 c.c. pure concentrated sulphuric acid, and boil till red fumes give way to white. When cold again, add 50 c.c. distilled water, stir, warm, and put by to settle. Filter off the clear solution, which should contain all the copper. Collect the filtrate in a clean glass beaker, and place in the beaker a perfectly clean and previously dried and weighed platinum dish or piece of foil. Connect with a two-cell Bunsen or Daniell battery, coupled for intensity. In about 10-12 hours, the electric current will have decomposed the solution, and caused a deposition of metallic copper on the platinum foil. This need only be dried and weighed.

*Lead.*

(a) *Sulphides.—Mix—*

	Grammes.	Troy gr.
Ore .. .. .	10	160
Potash cyanide .. .. .	30	480

cover with salt in crucible, fuse for  $\frac{1}{4}$ -hour; the lead comes out as a clean malleable button. Avoid unnecessary heat.

(b) *Carbonates and Oxides.—Fuse—*

	Grammes.	Troy gr.
Ore .. .. .	10	160
Soda bicarbonate .. .. .	15	240
Potash carbonate .. .. .	5	80
Argol .. .. .	5	80

under a salt cover, in a crucible, without lid if in muffle, heating gradually for first  $\frac{1}{4}$ -hour. Cool under lid, or pour.

*Tin.*

(a) Pack 5 grm. potash cyanide into the bottom of a crucible; then charge with 10 grm. ore mixed with 40 grm. cyanide; cover with 5 grm. cyanide, and fuse  $\frac{1}{4}$ -hour. The button comes out clean, bright, and free from iron; the impurities collect in the slag at the bottom of the crucible. The result is about  $\frac{1}{2}$  per cent. under that of chemical analysis. Associated minerals affect the result but little.

(b) Intimately mix and put in a clay crucible—

	Grammes.	Troy gr.
Ore .. .. .	5	80
Charcoal dust .. .. .	4-1	12-16
Covering with black flux or substitute (2 parts potas-soda carb., 1 part flour)	12 $\frac{1}{2}$ -15	200-240
Borax glass .. .. .	1-1 $\frac{1}{4}$	16-20

adding a salt cover and finally a piece of charcoal. Apply the lid, heat moderately at first and increase till boiling ceases, then at a white heat for  $\frac{1}{2}$ - $\frac{3}{4}$ -hour. Cool and break. The button comes out almost as well as in (a) and the result is nearly as accurate, while the cost is much less.

(c) *Separation of Tin and Antimony.—*(1) The powdered ore or slag is introduced into a nickel crucible and intimately mixed with about 10 times its weight of a mixture of sodium carbonate and 1 of borax, the decomposition being brought about by the application for a few minutes of a full red heat from an ordinary foot blow-pipe. When all necessary reaction has terminated, the contents may be poured on an iron slab. The melt thus obtained is readily and completely discoloured by a little dilute HCl, introduced into a flask of known capacity, together with the small quantity which still adheres to the sides of the crucible, which is readily detached by pouring in a further quantity of dilute acid and gently warming. The contents of the flask are diluted to the containing mark, and a

*Tin—continued.*

known quantity is withdrawn by a pipette, which is received into an accompanying flask, and saturated with a stream of  $\text{SH}_2$  gas. Tin, antimony, and similar metals of the same group, are precipitated as sulphides; the mixed precipitates are filtered and collected by a plug of cotton inserted in the neck of a glass funnel. The cotton with its contents after being once washed is dislodged and received into a vessel containing a strong solution of  $\text{NaHO}$ , raised to and maintained for a few minutes at boiling point, the tin and antimony sulphide passing into solution as sulphostannate and sulphoantimoniate of soda.

The soluble tin and antimony compounds thus obtained are separated by refiltering as in the previous filtration, and divided into two separate portions, being received for convenience sake into two flasks, and labelled A and B portions; to the A portion is introduced a somewhat large excess of oxalic acid, and the solution is allowed to boil until the small quantity of antimony sulphide that remains presents a pure orange-red precipitate, characteristic of that compound; the precipitate being collected in the usual manner and decomposed in a porcelain crucible at a very low red heat, weighing as  $\text{Sb}_2\text{O}_3$  and calculating to percentage of antimony.

To the second, or B portion, is added an excess of dilute  $\text{HCl}$ , and the whole is gently warmed; the reprecipitated sulphide thus obtained is treated precisely the same as in the previous instance, weighing as oxides, the total percentage of tin being obtained by deducting the former weight of precipitated oxide obtained from the A portion from that of the mixed oxides obtainable from the second or B portion, and calculating by its respective formula.

The speed and accuracy obtainable largely depend upon the judicious use of the borax, whereby not only a most readily fusible compound is obtained, but at the same time readily soluble in acid. (H. N. Warren.)

(2) The sample must first be reduced to as fine a condition as possible and in the case of a type metal, this is easily accomplished by paring with a knife. A weighed quantity of the sample is taken, placed in a beaker, and treated several times with concentrated  $\text{HNO}_3$ , evaporating nearly to dryness after each treatment. By this operation the Sb and Sn are converted into insoluble oxides. Remove to a filter and wash well with boiling water. After repeated washing with the water, treat again with  $\text{HNO}_3$ , and evaporate to complete dryness. Ignite to destroy the filter paper, transfer to a silver crucible, and ignite the residue with about 8 times its weight of pure  $\text{NaOH}$ . This fusion is best accomplished on a sand bath. If a higher temperature be employed, there is a danger of losing some of the substance, owing to the "spitting" which will take place. The fusing must be continued until the mass is completely liquid. Allow to cool and treat with hot water in a beaker, to dissolve out the tin, add rather a large quantity of water, then alcohol to about a third of the bulk of water used, and

*Tin*—continued.

allow to stand for 24 hours, with frequent stirring. Filter and wash well with 1 vol. alcohol to 2 vols. water. Fuse the insoluble again with NaOH as before, and repeat the treatment with hot water and alcohol, allowing to stand again for 24 hours as before. Filter and wash repeatedly with equal bulks of alcohol and water. Add the filtrates together = *Filtrate No. 1*.

The insoluble portion is now treated with a saturated solution of tartaric acid, to which a few drops of HCl have been added. This dissolves out the Sb, leaving behind any other impurity which may be present. Dilute largely with water, and pass  $\text{SH}_2$  gas, until the Sb is completely precipitated. Filter and dissolve precipitate in  $\text{HNO}_3$ , transfer to a porcelain crucible, and evaporate with fuming  $\text{HNO}_3$ . This evaporation, which must be repeated several times, drives off the free sulphur, destroys the filter paper, and oxidises the sulphide of antimony to  $\text{Sb}_2\text{O}_3$ . Dry and weigh, multiply the weight by  $\cdot 7893$ . The result is the weight of metallic Sb in the quantity of the sample taken.

**FILTRATE No. 1.**—This contains the whole of the tin in solution. Evaporate to about  $\frac{1}{2}$  of its bulk; add a few drops of HCl, and pass  $\text{SH}_2$  gas to precipitate the Sn as  $\text{SnS}_2$ . To obtain complete separation of the Sn, some care is necessary, the HCl must be but slightly in excess, and the solution must be kept hot to facilitate the formation of the sulphide. The best way to do this is to boil the liquid first, then saturate with the gas and boil again, repeating this process until the whole of the Sn is precipitated; filter, wash well with water, and ignite, allowing free access to the air. Weigh, and multiply by  $\cdot 7866$ ; the result equals the weight of metallic tin.

The great advantage of this method is the slight liability to loss, owing to the very insoluble nature of the precipitates. The manual dexterity required is not very great. The one chief drawback to the method is the length of time required to perform the entire operation, but this is amply compensated for by the accuracy of the results obtained. (*Chemical Trade Journal Prize Essays*.)

#### *Auriferous Mineral. (h.) (A. F. Crosse.)*

(Continued from p. 331.)

The following method is of great practical utility in determining the milling value of an auriferous ore, and at the same time indicating in outline the process likely to be best adapted for its treatment.

The mineral is prepared in the usual way so that it will pass through a 900-mesh sieve. One sample (A) is subjected to the ordinary fire assay in order to determine the *whole* amount of gold present. A duplicate sample (B) of, say, 1000 gr., is mixed with water, and shaken up for some time either in a well-closed copper vessel amalgamated inside, or in a wide-mouthed glass-stoppered bottle containing bits of amalgamated sheet copper, taking care



*Auriferous Mineral*—continued.

to avoid excess of mercury and any possibility of leakage. The residue (C) after continued shaking (when all free gold has become absorbed by the amalgamated surface) is poured into a filter, dried, and assayed. The difference between the fire assay of C and that of A will give the percentage of *free amalgamable* gold present in the ore.

The next step is to determine how much of the gold in the residue C is locked up in pyrites and how much is "float" gold. For this purpose a duplicate sample of the residue C is weighed into an elutriator, or sort of miniature *spitz-kusten*, being a conical vessel 7-8 in. high, with two holes, one near the bottom for admitting water, and a second at the bottom for letting out the water and ore after treatment. Water is furnished from a tap by means of a tin or rubber tube held in a clamp, the rate of flow being so adjusted that the level remains fairly constant. The stream being very slow and regular, it may be safely reckoned that all gold washed away by it would be similarly lost on any known form of concentrator.

The "float gold" (D) being thus washed away with the slimes, a fire assay of the concentrates (E) remaining in the elutriator will reveal by difference how much of the non-amalgamable gold is in pyrites and how much is float gold. Thus—

	Gold per ton.		
	oz.	dwt.	gr.
Original sample A gave.. .. .	1	1	0
Of this amount—			
Residue B gave .. .. .	0	5	12
Therefore, amalgamable gold = .. .. .	0	15	12
Of the 5½ dwt., there were found in E .. .. .	0	2	12
which is presumably pyritous,			
Leaving a balance of .. .. .	0	3	0
being float gold that escaped with the slimes.			

Table 142.—Alloys.

[illegible]

Table 142—continued.

[illegible]





Table 142—continued.

	Aluminum.	Antimony.	Arsenic.	Bismuth.	Cadmium.	Copper.	Gold.	Iron.	Lead.	Manganese.	Nickel.	Phosphorus.	Silicium.	Silver.	Tin.	Zinc.
Silicium brass	..	..	..	..	..	71.30	..	.38	.74	..	..	..	.14	..	.57	.26.65
" wire	..	..	..	..	..	99.94	..	trace	..	..	..	..	.02	..	.03	..
" "	..	..	..	..	..	97.12	..	trace	..	..	..	..	.05	..	1.14	1.62
Silver coin	..	..	..	..	..	7.5	..	..	..	..	..	..	..	..	..	..
Solder, aluminum	6	..	..	..	..	4	..	..	..	..	..	..	..	..	..	..
" brazing	..	..	..	..	..	1	..	..	2	..	..	..	..	..	..	..
" coarse..	..	..	..	..	..	..	..	..	1	..	..	..	..	..	1	..
" common	..	..	..	..	..	..	..	..	2	..	..	..	..	..	1	..
" "	..	..	..	..	..	..	..	..	1	..	..	..	..	..	1	..
" copper	..	..	..	..	..	63	..	..	1	..	..	..	..	..	2	..
" fine ..	..	..	..	..	..	47	..	..	1	..	..	..	..	..	47	..
" brass	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
" glaziers'	..	..	..	..	..	22.2	66.6	..	1	..	..	..	..	6	..	..
" gold	..	..	..	..	..	..	89	..	..	..	..	..	..	..	3	..
" "	..	..	..	..	..	4	..	..	..	..	..	..	..	..	..	..
" hard	..	..	..	..	..	3	..	..	..	..	..	..	..	..	..	..
" iron	..	..	..	..	..	2	..	..	..	..	..	..	..	..	..	..
" lead	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
" pewteers'	..	..	..	11.8	..	..	..	..	2	..	..	..	..	..	..	..
" "	..	..	..	22	..	..	..	..	29.4	..	..	..	..	..	..	..
" "	..	..	..	25	..	..	..	..	45	..	..	..	..	..	..	..
" "	..	..	..	40	..	..	..	..	25	..	..	..	..	..	..	..
" "	..	..	..	..	..	..	..	..	20	..	..	..	..	..	..	..
" plumbers' coarse	..	..	..	..	..	..	..	..	3	..	..	..	..	..	..	..
" fine	..	..	..	..	..	..	..	..	1	..	..	..	..	..	..	..
" fusible	..	..	..	..	..	..	..	..	1	..	..	..	..	..	..	..
" "	..	..	..	..	..	..	..	..	1	..	..	..	..	..	..	..
" "	..	..	..	..	..	..	..	..	1	..	..	..	..	..	..	..
" potmetal	..	..	..	3	..	..	..	..	3	..	..	..	..	..	..	..

Table 142—continued.

	Aluminum.	Antimony.	Arsenic.	Bismuth.	Cadmium.	Copper.	Gold.	Iron.	Lead.	Manganese.	Nickel.	Phosphorus.	Silicium.	Silver.	Tin.	Zinc.
Solder, silver ..	..	..	..	..	..	20	..	..	..	..	..	..	..	80	..	..
" " ..	..	..	..	..	21	32.3	..	..	..	..	..	..	..	38.5	..	29.2
" " soft..	..	..	..	..	..	12	..	..	..	..	..	..	..	67	..	..
" " spelter, hard	..	..	..	..	..	65	..	..	..	..	..	..	..	..	..	35
" " "	..	..	..	..	..	3	..	..	..	..	..	..	..	..	..	2
" " soft	..	..	..	..	..	1	..	..	..	..	..	..	..	..	..	1
" " tin ..	..	10	..	16	..	..	..	..	16	..	..	..	..	..	58	..
Speculum metal ..	..	..	12	..	..	66.6	..	..	..	..	..	..	..	..	33.3	..
" " "	..	..	..	..	..	66	..	..	..	..	..	..	..	..	22	..
Spelter, hard ..	..	..	..	..	..	50	..	..	..	..	..	..	..	..	29	21
" " soft ..	..	..	..	..	..	65	..	..	..	..	..	..	..	..	..	35
" " "	..	..	..	..	..	1	..	..	2-4	..	..	..	..	..	1-2	1
Stearo metal ..	..	..	..	..	..	55-60	..	..	..	..	..	..	..	..	..	34-44
Telescopic mirrors	..	..	..	..	..	66.6	..	..	..	..	..	..	..	..	33.4	..
Temper ..	..	..	..	..	..	33.4	..	..	..	..	..	..	..	..	66.6	..
Tombac ..	..	..	..	..	..	88.8	..	..	..	..	..	..	..	..	..	11.2
Tutenag ..	..	..	..	..	..	50	..	..	..	..	19	..	..	..	..	31
" " "	..	..	..	..	..	45.7	..	..	..	..	17.4	..	..	..	..	36.9
Type metal	..	25	..	..	..	..	..	..	75	..	..	..	..	..	..	..
" " "	..	25	..	..	..	..	..	..	50	..	..	..	..	..	25	..
" " "	..	12.5	..	..	..	..	..	..	87.5	..	..	..	..	..	..	..
White metal ..	..	56.8	..	..	..	7.4	..	..	..	..	..	..	..	..	28.4	7.4
" " "	..	..	..	..	..	69.8	..	..	..	..	..	..	..	..	4.4	25.8
" " "	..	7	..	..	..	3	..	..	..	..	..	..	..	..	90	..
" " "	..	42	..	..	..	6	..	..	42	..	..	..	..	..	..	..

*Action of Acid and Alkaline Solutions on Metals. (Lunge.)*

At ordinary temperatures, and with exclusion of air, the action of sulphuric acid, pure or commercial, at strengths of 66° to 50° B., is very insignificant on cast iron, and noteworthy differences as regards the various qualities of iron could not be distinguished. At the boiling point of water the action is much greater, that of acid at 66° B. being the slightest, that of acid at 60° B.  $1\frac{1}{2}$  times greater, and that of acid at 50° B. three times greater.

The differences at the boiling points of the acids are much more decided. Acid of 66° B. has little more action at its boiling point (295°) than at 100°; acid of 60° B. acts at its boiling point (200°) on the average 14 times stronger than at 100°, and 20 times stronger than the 66° acid at 295°. The 50° B. acid, which at 100° acts twice as strongly as that of 60° B., acts at its boiling point (147°) less strongly than that of 60° B. at 200°.

As to the action of monohydrated sulphuric acid upon cast iron, wrought iron, copper, and lead, at common temperatures and at 100° there is very little action, either upon cast or wrought iron, if air is excluded. Copper and lead are strongly attacked at common temperatures—lead more than copper. At 100°, lead is scarcely more affected than at 20°, while copper enters into violent reaction, with escape of sulphurous acid.

With saturated solutions of sodium chloride and ammonium chloride upon the same metals. Sodium chloride attacks slightly in all cases, but quite perceptibly, especially on cast iron, and at higher temperatures on lead. The action of ammonium chloride is much stronger. Contrary to the common opinion, lead is much more attacked in the cold by a strong solution of sal ammoniac than iron. At a boiling heat it resists far better than iron, but far worse than copper.

Caustic soda has little action upon iron at 15° and 100°, but more upon wrought iron than cast iron. Upon copper the action is more considerable, and upon lead still more so if the lye is dilute. Sodium sulphide, even in dilute solution, has a much stronger action upon iron and copper. Upon lead the action is slight, even at 100°. Sodium sulphate has little effect upon copper and lead, but its action upon iron is considerable.



Table 143.—*Properties of Metals.*[illegible]

Table 143—continued.

Metal.	Symbol.	Sp. gr.	Atomic weight.	Fusing point. ° F.	Expansion of 1 from 32° to 212° F.	Tensile strength per sq. in. Tons.	Weight per cub. ft. lb.	Tenacity. lb.	Malleability.	Ductility.	Heat conductivity.	Electric conductivity.	Affinity for sulphur.
Gallium	Ga	5.9	70.0	86	..	..	..	..	..	..	..	..	..
Germanium	Ge	..	72.3	..	..	..	..	..	..	..	..	..	..
Glucinum	Gl	..	9.0	..	..	..	..	..	..	..	..	..	..
Gold	Au	19.2	196.7	2192	..	..	..	12	1	1	2	779	..
Hydrogen	H	..	1.0	[2000]	..	..	..	..	..	..	..	..	..
Indium	In	7.4	113.7	347	..	..	..	..	..	..	..	..	..
Iodine	I	4.9	127.0	221	..	..	..	..	..	..	..	..	..
Iridium	Ir	22.4	193.0	4530	..	..	..	..	..	..	..	..	..
Iron	Fe	7.8	56.0	2700	..	..	..	27.5	8	4	6	168	13
" cast	..	..	..	3280	..	..	450	..	..	..	..	..	..
" wrought	..	..	..	3300	..	7.32	488	42	..	..	..	..	..
" steel	..	..	..	[4000]	..	..	..	..	..	..	..	..	..
Lanthanum	La	6.1	138.8	..	..	..	..	..	..	..	..	..	..
Lead	Pb	11.4	206.9	635	..	..	..	1	6	10	9	83	9
Lithium	Li	0.59	7.0	[617]	..	..	..	..	..	..	..	..	..
Magnesium	Mg	1.7	24.0	356	..	..	..	..	..	..	..	..	..
Manganese	Mn	8.0	55.0	3450	..	..	..	..	..	..	..	..	16

2  
2  
2



Table 143—continued.

[illegible]



Table 145.—*Weight of Various Rolled Metals in lb. per lineal ft.*

Size of Bar.	Iron.		Phosphor-Bronze.		Bull's Metal.	
	Square	Round.	Square.	Round.	Square	Round.
in.						
$\frac{1}{16}$	•209	•164	•24	•19	•225	•177
$\frac{1}{8}$	•326	•256	•38	•30	•353	•278
$\frac{3}{16}$	•470	•369	•55	•43	•510	•400
$\frac{1}{4}$	•640	•502	•74	•58	•690	•541
$\frac{5}{16}$	•835	•656	•97	•76	•902	•708
$\frac{3}{8}$	1•057	•831	1•23	•96	1•144	•895
$\frac{7}{16}$	1•305	1•025	1•52	1•19	1•412	1•107
$\frac{1}{2}$	1•579	1•241	1•83	1•44	1•70	1•34
$\frac{9}{16}$	1•879	1•476	2•18	1•72	2•03	1•60
$\frac{5}{8}$	2•205	1•732	2•56	2•01	2•38	1•86
$\frac{3}{4}$	2•556	2•011	2•97	2•33	2•76	2•17
$\frac{7}{8}$	2•936	2•306	3•41	2•68	3•17	2•49
1	3•34	2•62	3•88	3•05	3•61	2•83
$1\frac{1}{16}$	3•76	2•96	4•38	3•44	4•07	3•20
$1\frac{1}{8}$	4•22	3•32	4•91	3•86	4•56	3•54
$1\frac{1}{4}$	4•71	3•68	5•47	4•30	5•09	4•00
$1\frac{3}{8}$	5•25	4•09	6•06	4•77	5•65	4•43
$1\frac{1}{2}$	5•77	4•50	6•68	5•25	6•23	4•87
$1\frac{5}{8}$	6•35	4•96	7•34	5•77	6•85	5•37
$1\frac{3}{4}$	6•90	5•41	8•02	6•30	7•46	5•85
$1\frac{7}{8}$	7•51	5•90	8•73	6•86	8•12	6•38
$2$	8•12	6•38	9•48	7•45	8•80	6•92
$2\frac{1}{16}$	8•72	6•92	10•25	8•05	9•54	7•49
$2\frac{1}{8}$	9•51	7•44	11•05	8•69	10•24	8•07
$2\frac{1}{4}$	10•29	8•03	11•89	9•34	11•09	8•69
$2\frac{3}{8}$	10•97	8•59	12•75	10•02	11•86	9•31
$2\frac{1}{2}$	11•74	9•22	13•65	10•72	12•69	9•97
$2\frac{5}{8}$	12•52	9•82	14•57	11•45	13•55	10•64
$2\frac{3}{4}$	13•36	10•49	15•53	12•20	14•45	11•35
$2\frac{7}{8}$	14•20	11•14	16•51	12•97	15•36	12•06
$3$	15•08	11•84	17•53	13•77	16•31	12•81
$3\frac{1}{16}$	15•97	12•53	18•58	14•60	17•28	13•57
$3\frac{1}{8}$	16•91	13•27	19•65	15•44	18•28	14•36
$3\frac{1}{4}$	17•85	14•01	20•76	16•31	19•31	15•16
$3\frac{3}{8}$	18•84	14•79	21•90	17•20	20•37	16•00
$3\frac{1}{2}$	19•83	15•57	23•06	18•12	21•45	16•85
$3\frac{5}{8}$	20•87	16•39	24•26	19•06	22•57	17•73
$3\frac{3}{4}$	23•11	18•07	26•75	21•02	24•93	19•55
$4$	25•26	19•84	29•36	23•07	27•31	21•46
$4\frac{1}{16}$	27•61	21•68	32•06	25•21	29•84	23•45
$4\frac{1}{8}$	30•07	23•60	34•94	27•45	32•51	25•53
$4\frac{1}{4}$	35•28	27•70	41•01	32•20	38•15	29•95
$4\frac{3}{8}$	40•91	32•13	47•56	37•34	44•24	34•74
$4\frac{1}{2}$	46•97	36•89	54•57	42•87	50•77	39•88
$4\frac{5}{8}$	53•44	41•97	62•1	48•78	57•77	45•38
$4\frac{3}{4}$	60•32	47•38	70•1	55•05	65•21	51•22
$5$	67•63	53•12	78•28	61•48	73•95	57•30
$5\frac{1}{16}$	75•35	59•18	87•6	68•8	81•48	64•00
$5\frac{1}{8}$	83•51	65•58	97•00	76•18	90•26	70•88
$5\frac{1}{4}$	92•46	72•30	107•00	84•04	99•73	78•17
$5\frac{3}{8}$	101•03	79•35	117•5	92•3	109•27	85•83
$5\frac{1}{2}$	110•43	86•73	128•35	101•7	119•39	94•22
$5\frac{5}{8}$	120•25	94•43	139•7	109•8	130	102•12
6						
12	481	377•9	559	439	520	408•5



Table 147.—Working Strains of Bolts in Various Metals.

Diameters.		Nett Area: sq. in.	Working Strain in lbs.					
in.	Under Thread.		A 4000 lb. per sq. in.	5000 lb. per sq. in.	B 6000 lb. per sq. in.	7000 lb. per sq. in.	C 8000 lb. per sq. in.	D 10,000 lb. per sq. in.
$\frac{1}{8}$	.295	.0683	273	341	410	478	546	683
$\frac{3}{16}$	.393	.1313	485	606	728	849	970	1,213
$\frac{1}{4}$	.509	.2034	814	1,017	1,220	1,423	1,627	2,034
$\frac{5}{16}$	.622	.3038	1,215	1,519	1,823	2,127	2,430	3,038
$\frac{3}{8}$	.733	.4219	1,688	2,110	2,531	2,953	3,375	4,219
1	.840	.5541	2,216	2,770	3,325	3,879	4,433	5,541
$1\frac{1}{8}$	.942	.6969	2,788	3,475	4,181	4,878	5,575	6,969
$1\frac{1}{4}$	1.067	.8941	3,576	4,470	5,365	6,259	7,153	8,941
$1\frac{3}{8}$	1.162	1.0604	4,242	5,301	6,362	7,422	8,483	10,604
$1\frac{1}{2}$	1.27	1.3069	5,204	6,505	7,805	9,106	10,407	13,009
$1\frac{3}{4}$	1.369	1.4720	5,888	7,360	8,832	10,304	11,776	14,720
$1\frac{7}{8}$	1.494	1.7530	7,012	8,765	10,518	12,271	14,024	17,530
2	1.715	1.9855	7,942	9,928	11,931	13,917	15,884	19,855
$2\frac{1}{8}$	1.930	2.2900	9,240	11,550	13,860	16,170	18,480	23,100
$2\frac{1}{4}$	2.180	2.9255	11,702	14,627	17,553	20,478	23,404	29,255
$2\frac{3}{8}$	2.384	3.7325	14,930	18,662	22,395	26,127	29,860	37,325
3	2.634	4.4637	17,855	22,319	26,182	31,246	35,710	44,637
$3\frac{1}{8}$	3.105	5.4490	21,796	27,245	32,694	38,143	43,592	54,490
$3\frac{1}{4}$	3.572	7.572	30,288	37,860	45,432	53,004	60,576	75,720
4	3.573	10.040	40,160	50,200	60,240	70,280	80,320	100,400
$4\frac{1}{8}$	4.54	12.910	51,640	64,550	77,460	90,370	103,280	129,100
5	4.534	16.140	64,560	80,700	96,840	112,980	129,120	161,400
6	5.487	23.600	94,400	118,000	141,600	165,200	188,800	236,000

A—Suitable for wrought iron, rolled Muntz metal and cast phosphor-bronze. B—Suitable for mild steel and forged Bull's metal.

C—Suitable for superior steel, rolled Bull's metal and rolled phosphor-bronze.

D—Suitable for cold rolled steel, cold rolled Bull's metal, and cold rolled phosphor-bronze.



## VALUING METALS AND ORES.

*Aluminium.*—The mineral worked as a source of the metal should be as free as possible from iron, and as rich as possible in alumina. Cryolite, consisting when pure of 13 per cent. aluminium, combined with 54 of fluorine and 33 of sodium, is always more or less contaminated with iron and silicon compounds which give much trouble; when the total impurities reach 20 per cent. the mineral is commercially worthless. Bauxite, affording about half its weight of alumina, is liable to the same faults. Average samples will show 55-58 per cent. alumina, 3-20 per cent. silica, 2-25 per cent. iron oxide, 11-30 per cent. water; the maximum figures of silica and iron lower the value greatly. The same may be said of kaolins as a source of the metal.

Aluminium should contain no silica or iron, but it may safely be said that all found in commerce does contain both. The silica occurs in two forms—as a silicide of aluminium and in the graphitoidal form. Commercial brands show the following composition:—

	%
Aluminium .. .. .	95-99.30
Iron .. .. .	.03- 3.25
Silicon combined .. .. .	.23- 1.75
„ graphitoidal .. .. .	.13- 1.35
Copper .. .. .	nil- .10
Sodium .. .. .	nil- .30
Lead .. .. .	nil- .04

*Antimony.*—Ores of antimony, the oxide and sulphide, are sold on a basis of 45 per cent. of metal, the market value per ton being of course liable to fluctuate in sympathy with the current price of the metal. These fluctuations are apt to be sudden and considerable. Each unit above 45 per cent. is worth so much per ton extra, say 8s. to 9s. per unit when the standard is worth 25s. a ton; while ore carrying less than 45 per cent. is subject to a discount at the same ratio, so that with a poor ore it is obvious that a limit is soon reached when the price becomes a negative quantity. Other conditions, such as size and impurities, further affect the market value. Thus, in dressing the ore it is essential that it should not be reduced in size much below that of hazel nuts. Of the impurities, especially in the sulphide, the worst is lead; 1 per cent. of lead will often make an otherwise good ore unsaleable. Copper, arsenic, and zinc are also objectionable, and reduce the value. Silver adds to the value if in appreciable quantity. The usual basis of sale is the assay value of metal computed on the dry ore. Nevertheless, smelters often prefer to base their offer for a parcel on the result of an actual smelting of a sample of two or

*Antimony*—continued.

three cwt., which enables them to judge of the behaviour of the ore in the furnace, whether it yields its metal readily, and does not suffer much loss in the slag.

*Copper*.—Though a large proportion of the copper and copper ores now brought into the market are sold by assay, the antiquated and cumbersome system of “ticketing” still survives sufficiently to demand description here.

“Ticketings,” as held in Cornwall and Wales, are periodical auctions, at which buyers make bids (written on tickets) for such parcels of ore as they may have previously sampled and assayed. The value of the parcel is worked out as follows.

The “standard” is the actual value per ton of twenty-one cwt. of the fine copper contained in the ore, which is made up of the price paid for it added to the “returning charges,” or cost incurred in extracting it from the ore. Then the market value of the parcel of ore is the amount arrived at by reckoning the “settled produce” or fine copper yielded by it at standard, and deducting the returning charges. These latter vary. In Cornwall they are fixed at 55s. per ton of ore, whether the ore is rich or poor. In Swansea they vary with the character of the ore, and consist of two items, one being a fixed rate of 12s. 2d. per ton of ore, and the other a charge of 3s. 9d. per unit of metal in the ore. The following examples calculated out will make the matter clearer:—

*A. Finding Standard.*—(Cornwall).

328 tons ore gave 21 tons fine copper, or about 6·4 per cent.

328 tons × 55s. returning charges=	902	0	0	
Ticket offer for parcel	=	820	0	0

21 tons fine copper into .. ..	1722	0	0
--------------------------------	------	---	---

Gives a standard of .. ..	£82	0	0	per ton.
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*B. Finding “Value” of Parcel.*—(Cornwall).

76 tons ore at 4·55 per cent.	=	3·45	tons fine copper.
Multiplied by .. .. .		82½	per ton. „

282 18 0

Less returning charges at 55s. on 76 tons =	209	0	0
---	-----	---	---

Value of parcel =	£73	18	0
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*C. Finding “Returning Charges”*—(Swansea).

Ore at 5·75 per cent.

Fixed charge	=	0	12	2	per ton.
Sliding charge at 3s. 9d. per unit on 5·75 %	=	1	1	6	„

Total returning charges =	£1	13	8	„
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*Copper*—continued.

The presence of .25 per cent. arsenic, or of .01–.1 per cent. antimony, bismuth, or sulphur, or of 1–2 per cent. lead, is injurious. For electrical purposes, lead renders it unsaleable; but for many purposes a small amount of arsenic does not affect the value.

*Iron*.—Phosphorus is the most harmful impurity, and next ranks sulphur. An appreciable percentage of either will condemn a sample.

*Lead*.—Antimony, silver, and zinc are all detrimental. For pigment making, the presence of zinc does not so much matter, as the salt is white. For sheet lead for chemical manufacturers' purposes, the impurities named must be absent. Zinc not only reduces the value of the lead produced, but it also causes losses of metal by volatilisation and formation of fume. Antimony and arsenical pyrites are even more troublesome in this respect. Barytes interferes with the smelting operations and increases the consumption of fuel. The ore is valued for its lead contents per ton of 21 cwt. dry. Many lead ores contain silver. This does not add to the value of the sample unless it exceeds 5 oz. per ton. Against the assay value of the ore there is deducted a "returning charge," which varies according to the cost of fuel, rates of carriage, &c., and generally ranges between 2*l.* and 3*l.* a ton.

*Manganese*.—For Spanish and similar ores, the normal strength is 70 per cent.  $MnO_2$  in the ore dried at 212° F.; which means that 100 parts by weight of the ore liberate as much chlorine as 70 parts of pure  $MnO_2$  would do. The price of such ore fluctuates generally around 4*l.* per ton, with an addition or deduction of 2*s.* 6*d.* per unit for higher or lower quality, the minimum being usually 65 per cent. In the case of German ores, the normal strength is 60 per cent., the minimum 57 per cent., and the price per unit 2*s.* up or down. Of impurities, the most injurious are carbonates (of lime, &c.), as they not only consume hydrochloric acid, but also evolve carbonic acid, which has a most deleterious effect in bleaching-powder manufacture. The physical character of the ore is of some consequence, the soft varieties being most easily soluble in the acid, and therefore preferred. Some high-grade ores are so hard as to consume an excess of acid and steam, which greatly lowers their market value.

*Nickel*.—The presence of copper is highly injurious, as it cannot be separated except by wet process. Nevertheless, scarcely any ores are entirely free from copper.

*Tin*.—The confusing and old-fashioned method of computing the value of tin ore, by which the ignorant seller was robbed of at least one-third of the worth of his parcel, is now replaced by an accurate assay; the percentage of pure tin being worked out as tin oxide (black tin).

The presence of titanium does not affect the value to any

*Tin*—continued.

extent; but tungsten lowers the value; though, when a market can be found for the product, the ore may be freed from tungsten by treating with soda sulphate, and washing out the soda tungstate.

*Zinc*.—The chief deleterious ingredient of zinc ores is lead. The only ores absolutely free from lead are those from Lehigh. All others contain some small proportion, say .01 per cent. Antimony, arsenic, cadmium, copper, iron, and lead are injurious both in the roasting of blende and in the subsequent distilling of the oxide. The smelter who buys blende or calamine bases his estimate of the value of a parcel of ore to him in somewhat the following way. He takes the market price of spelter, which may be assumed at 20*l.* a ton; from this he deducts 6*l.* per ton as the cost of smelting. Then from the zinc contents of the ore by assay, say 45 per cent., he deducts 15 per cent. if blende or 10 per cent. if calamine, as being the proportion of metal which will be lost in the slags and vapours, so that he has 30 or 35 per cent. of metal which he can reckon on extracting. Thus the market value of the zinc product of the ore is arrived at by a rule of three sum, e. g.,

As  $\frac{\text{Spelter}}{100\%}$  is worth 14*l.* a ton, then  $\frac{\text{Blende}}{30\%}$  is worth 4*l.* 4*s.*

But as the smelter must make a profit, he offers such a figure below 4*l.* 4*s.* as will leave him the margin he desires. When the ore is very impure, more than 15 per cent. will be lost in the slags, &c.

## ROASTING PYRITES.

The practice of roasting pyrites is almost as old as the gold-mining industry itself, and its importance is increasing rather than diminishing. It is true that some of the recently introduced chemical processes for recovering gold from sulphides have achieved a measure of success, but at present they are too costly to warrant their application to the thousands of tons of low-grade sulphurets being annually produced, and therefore it may be truly said that the problem of cheaply extracting small percentages of gold from refractory ores remains unsolved by them. About the sweet-roasting of auriferous sulphides and arseno-sulphides as a preliminary to amalgamation, there is the charm of simplicity, and hence it comes that the leading authorities of the day are looking to the invention of an improved furnace as the only efficient solution of the difficulty which is responsible for many mines being shut down or abandoned, and which is curtailing the income of almost every one. There is to-day certainly no subject connected with gold-mining which demands more careful consideration.

An experience of over 20 years with numerous forms of pyrites furnace leads the author to believe that in many instances the simplicity of the process has been the stumbling-block; that is to say, that operations have been undertaken with too little attention to the needs of the case. No doubt the liberation of sulphur and arsenic from an ore by means of heat is a very easy matter. A low temperature only is necessary, and the consumption of fuel is minimised by the fact that the sulphur and arsenic can be made to support their own combustion. For instance, in the sulphuric acid industry, where the primary object in roasting the pyrites is to recover the liberated sulphur as sulphurous oxide (except where the cinders are treated for copper), the ore is burned in thick beds in furnaces without any fuel whatever, the oxygen of the air admitted sufficing to support the combustion of the sulphur. In theory, while the combustion of coal produces a temperature of  $2787^{\circ}\text{C}$ ., the combustion of iron pyrites should produce at least  $1000^{\circ}\text{C}$ ., which is a higher temperature than is necessary for the operation, and allows a liberal margin for waste and imperfect combustion.

In the sulphuric acid makers' pyrites-kiln we have the simplest phase of the operation of sweet-roasting. The ores used, too, differ but slightly in their essential composition; yet even here, variations in the physical characters of ores will demand radically different types of furnace. Then it may be easily imagined that where the foremost object of the roasting is rather the destruction than the utilisation of the sulphur, followed by treatment of the cinders or residue for the recovery of very small proportions of a very valuable constituent, and where the compositions and charac-

ters of the ores dealt with are widely divergent, a new set of conditions are introduced.

In the first place, the oxidation and removal of the sulphur, arsenic, &c., must be complete and not merely partial; imperfectly decomposed pyrites is worse than unroasted for causing the mercury to flour, and thereby creating a loss of gold and amalgam. The conditions necessary to ensure sweet-roasting are a sufficient temperature, an abundant supply of fresh air, and an effective rabbling or distribution of the ore. Indications of perfect roasting are, that the hot ore emits neither sparks, fumes, nor odour on being stirred.

The effect of too little heat being employed will be not only that the ore is not sweetened, but that some of the freed gold may become coated with a film sufficient to repel the mercury. Too high a temperature, on the other hand, may cause a caking or fritting of the particles, and, in the absence of a full supply of air, a slag of mono-sulphide of iron may form, from which the recovery of the gold would be more difficult than before. Sometimes sand is introduced to prevent caking, and charcoal to promote decomposition, the carbon combining with the sulphur; but neither should be necessary, and the latter would be positively detrimental in presence of antimony or lead.

Now let us see what means have been adopted on the various gold fields to achieve the sweet-roasting of the auriferous sulphurets.

Foremost in point of popularity is the reverberatory furnace of multitudinous forms. Here the crushed ore is fed automatically or by hand (often the latter) into the upper portion of a slightly inclined chamber, and is gradually worked down the slope, by the periodical introduction of a rabbling tool through side doors in the chamber, always encountering a stream of hot gases from a fireplace at the bottom of the slope. The disengaged fumes from the ore are carried away into flues and condensers by the flow of products of combustion from the fireplace. The great and glaring faults of this system may be catalogued thus:—

- (1) Excessive consumption of fuel.
- (2) Employment of much labour.
- (3) Slowness of operation, which is largely due to—
- (4) The fact that only the surface of a body of ore is exposed to the oxidising influence, while—
- (5) The current of "air" which is to effect the oxidation is first robbed of its oxygen to support the combustion of the fire in the fireplace, so that the oxidising current is chiefly composed of carbonic acid!

The practical result of all this blundering is that the operation costs 10s. to 20s. a ton for wages and 8s. to 15s. a ton for fuel, and the total expenses would not be covered by 1 oz. of gold per ton. But the efficiency may reach as high even as 98½ per cent.

A step in advance was the revolving cylinder. In this fault (K)

survives to the full extent; faults (1), (3), and (4) are moderated, while fault (2) is replaced by a new one, viz. the expenditure of power in causing the cylinder to revolve.

The rotating-bed furnaces perpetuate many of the errors of the revolving cylinders, but to Sergeant and Flude's belongs the merit of being the first to provide an independent (but intermittent) supply of heated fresh air for oxidising purposes, the ore being kept distinct from the products of combustion derived from the fire. Moreover, the inventors utilise the sulphurous acid evolved.

Next come the shaft furnaces, two forms of which are extensively used, each giving satisfaction in its particular range of application—the Gerstenhöfer in Europe and the Stetefeldt in America. These are really reverberatory furnaces in principle, only built vertically instead of horizontally.

Gerstenhöfer's furnace carries out to the full the principle of making the pyrites support its own combustion. The powdered ore falls down a shaft, its descent being delayed by a number of crossbars which break up the stream and help to cause the exposure of every particle to the rising current of air at the base of the shaft. When the furnace has once been heated to redness, no further fuel is needed to maintain the operation. The oxide generated is utilised for making sulphuric acid, the fact of pyrites being the main object of the furnace, though found as the chief fault seems to be that the temperature is not sufficient to be under control, and that there is frequently a sintering of the ore, which is checked by adding spent ore to the charge.

Stetefeldt's furnace was designed for chloridising silver ores. It consists of a plain shaft, down which the ore falls in a thin steady shower, encountering the heated vapours and products of combustion from fireplaces at the base, and currents of cold air admitted from the sides. This furnace has done excellent service in the silver industry and has a world-wide reputation, but is not without faults. Thus, the unimpeded fall of the ore renders its passage too rapid for complete oxidation to take place, added to which the gases from the fire mingle with the ore, and necessitate the admission of a large extra supply of oxygen, which, entering as cold air, reduces the temperature and compels an additional consumption of fuel. Hence the cost of roasting is greater than it should be, the labour reaching from 3s. to 4s. a ton, and the fuel from 2s. to 3s. 6d. a ton. Moreover, the sulphurous oxide cannot be utilised.

Sufficient has been said to show that all these furnaces leave much to be desired when dealing with auriferous sulphides. Their capacity is too small, their action is too slow and incomplete, they require too much manual labour, they consume too much fuel, they make no provision for the after-treatment of the cinders, and they render the operation too costly. One or more of these draw-

backs is present in every case. What, then, are the conditions which an ideal furnace should fulfil? Practically these:—

- (a) *Regular and automatic feed and discharge.*
- (b) *Self-supporting combustion.*
- (c) *Utilisation of all products.*
- (d) *Accessibility for repairs.*
- (e) *Total cost of treatment under 2s. ( $\frac{1}{2}$  dwt.) per ton.*

Given the first three conditions, the fifth will take care of itself. Indeed, judging from recent experiments on sulphides in bulk, I believe the cost may be reduced to less than 1s. a ton, in the case of clean ores rich in sulphur.

A sectional illustration of the furnace which bids fair to accomplish these ends is shown in Fig. 56. It is the invention of Mr. Charles J. Fauvel, who while cleverly adapting such good features as were to be found in existing furnaces, set himself to remedy their defects, with a result that is highly promising. As may be imagined, this result was not arrived at in a moment, nor is it to be supposed that finality is reached. Modifications and improvements in the details will no doubt be dictated by special circumstances of localities where the furnace is to be used; but taken as it stands, it is thoroughly sound in principle, and provides in a most practical manner for all reasonable conditions, as will be seen from the following description.

The fireplace A is constructed so that it will burn coal, coke, or wood. Its side walls are provided with small air-holes for the admission of an extra supply of atmospheric air, so as to ensure perfect combustion, thus saving a waste of fuel, and at the same time avoiding the possibility of any free carburetted hydrogen passing away into the flues, with a risk of causing explosion. The fire is so directed that its greatest heat is developed just where it is required, viz., under the lowest slab B of the oxidising tower C. The fireplace A is built in duplicate, thus giving a greater command of heat at starting, or whenever it may be needed.

The oxidising tower C, in which the oxidation of the sulphides, &c., is accomplished, consists of a square brick structure about 40 ft. high, fitted inside with a series of sloping slabs D made of firelump, and projecting alternately from opposite walls of the tower C by which they are supported.

These slabs D stretch diagonally across almost the entire width of the tower, so that whatever enters at the top of the tower must pass over the whole surface of each slab in rotation until it can escape at the bottom. Beneath each slab is carried a flue E direct from the fireplace A, and conveying the necessary heat to the under side of the slab D. These flues E have no connection with the interior F of the oxidising tower C, so that the products of combustion of the fuel in the fireplace never come into contact with the ore. This fact in itself is sufficient to distinguish Fauvel's furnace from all others of the kind, and to render it far superior to them from a metallurgical point of view.



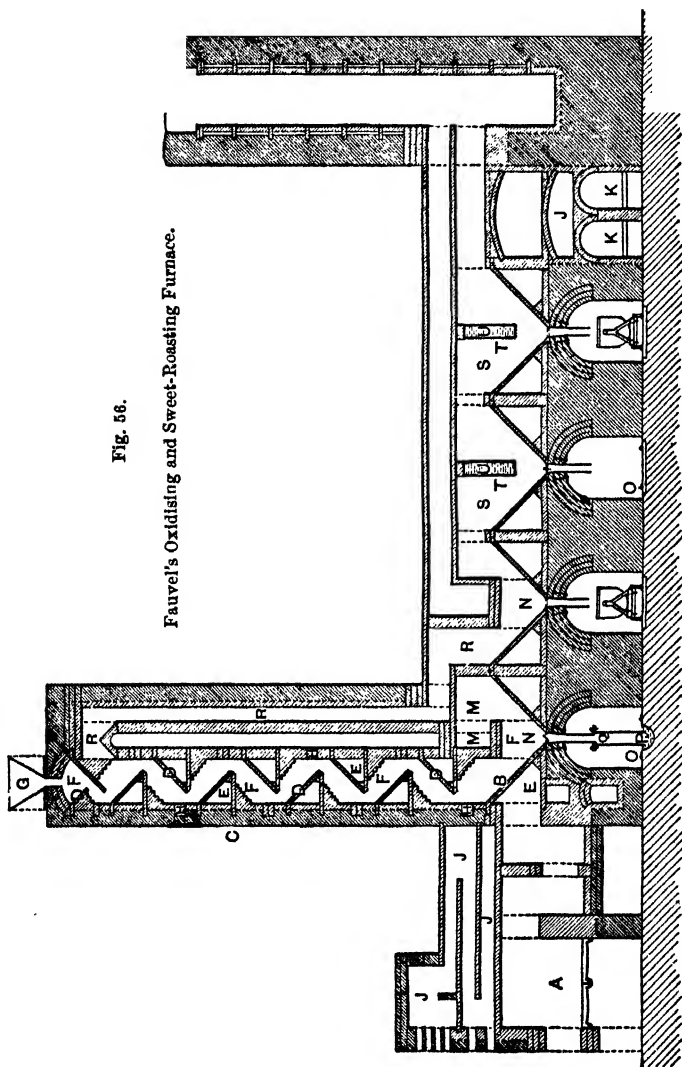


Fig. 56.

Fauvel's Oxidizing and Sweet-Roasting Furnace.

At the top of the oxidising tower C is an automatic feeder G, consisting of a rifle-grooved cylinder working in a hopper, so arranged that the finely ground ore is distributed in a thin regular shower across the whole width of the tower. As the ore passes down the tower, it falls successively upon the hot sloping shelves D, rolling across them in a constant stream, and dropping from one to the next.

The angle and adjustment of the shelves D are such that the whole surface of each slab does its full share of the work, the ore particles being kept in a state of incandescence during the time they are in contact with the slabs.

The wear and tear inside the tower is reduced to a minimum by avoiding all ironwork in its internal construction, and by making the slabs self-supporting. As a further provision in case of accidental injury to or flaw in the slab, each is built in independently of all the others, and the inner and side walls of the tower consist of a series of brick arches H, so turned that by them any slab can be separately reached, removed, and replaced with the least possible inconvenience and cost, and without in any way disturbing the rest of the tower, or weakening the structure.

During the whole of their passage downwards through the tower, the ore particles encounter an abundant upward stream of hot air, which is provided by means of special chambers J, placed above the fireplace A and over a secondary fireplace K, built near the base of the chimney L. These air-heating chambers J are furnished with adjustable doors, so that the air supply can be regulated to suit the ore under treatment. This stream of heated air, kept free from the products of combustion in the fireplace, flows up through the oxidising tower F in such a manner that it meets the incandescent particles of falling ore, checking them in their descent, and scattering them in such a way that it is impossible for any particle to escape the complete oxidation and removal of its associated sulphur, arsenic, antimony, or tellurium compounds. This admission of pure hot air is another feature in which the Fauvel furnace is distinctly in advance of others, all the oxygen contained in the air being available for oxidising and sweetening the ore, instead of being largely consumed in completing the combustion of the gases from the fireplace A.

The first principles of sweet-roasting demand that the ore shall encounter a gradually rising temperature. For this reason, the topmost shelves in the tower have no heating flue beneath them, and hence are relatively cool.

On the other hand, the lowest shelves are in direct contact with the fullest heat from the fire as it leaves the fireplace. In addition, the stream of heated air enters at M, near the bottom of the tower, and helps both by its own heat and by perfecting the oxidation at that point, to raise the temperature to the highest degree just where its effect is needed. Moreover, the air is purest on meeting the ore as it approaches the completion of its oxidation; whereas

in other furnaces the oxidising power of the air admitted is all used up at an early stage, and thus the last traces of sulphur, &c., are only imperfectly removed. In the Fauvel furnace the ore encounters a gradually rising temperature combined with increasingly pure air, so that the culminating points of the heating and oxidation coincide, and mark the termination of the process. On these accounts the sweetening of the ore is done much more rapidly and efficiently than by other furnaces.

By the time the ore has passed through the oxidising tower F it is completely sweetened. In this state it falls into a settling pit N situated immediately beneath the tower. This pit may be of ordinary construction, or provided with trucks and rails O for facilitating the withdrawal of the roasted ore for further treatment.

This generally consists in wet amalgamation, after the ore has been spread on a cooling floor, entailing much labour, waste of time, and the risk of losing a portion of the gold. Another evil sometimes arising from the roasting process is that the little particles of gold become glazed, as it were, with a microscopic coating of iron oxide, sufficient to prevent that intimate contact with the mercury which is absolutely essential to success in catching the gold by amalgamation.

As water must play an important part in the final amalgamation, and the power of water as a vehicle for transporting finely ground material is familiar to all gold miners, the idea suggested itself that the cumbersome system of trucks and cooling floors might be advantageously replaced by a running stream of cold water. Acting upon this, Fauvel made a number of experiments on the effects of quenching the incandescent ore in a bath of cold water. The results surpassed all expectation. Each glowing particle as it falls into the water causes an instantaneous generation of steam, accompanied by a report as of a miniature explosion. At the same moment, any glaze or skin which may have formed on the particles is ruptured, and they are broken down to a remarkably fine state and rendered very brittle. So much is this the case that an arsenical pyrites, which had been crushed only to pass a 30-mesh sieve, was, after roasting and quenching, rendered an impalpable powder. The importance of this innovation can hardly be exaggerated. In the first place, exceedingly fine crushing is not necessary, and therefore the output of the mill can be very much increased. In the second place, the ore is reduced to such a microscopic size that there is no longer any room for atoms of gold to be locked up in it. Thirdly, the skin of oxide, which is so apt to coat the grains, is removed, and the gold is rendered clean and shining, so that the tiny specks of precious metal can, with a lens, be seen scattered through the mass, and are thus in a condition specially adapted to amalgamation.

The only precaution found to be necessary, in order to be sure of attaining this end, is that the water be kept in a turbulent state,

otherwise the bubbles of steam, generated by the falling atoms of ore, enable them to float and accumulate on the surface of the water, instead of undergoing immediate and complete immersion.

The practical outcome of these experiments is, that the oxidised and sweetened ore is by Fauvel's system made to fall direct from the oxidising tower into a constantly running stream of cold water P, kept in a state of agitation by the introduction of spray pipes Q near the point where the ore falls into the water. The particles are thus at the same moment cooled, broken down and transported by the stream to a series of settlers, where the heavier and valuable portions collect, and from which they are raised by elevators and delivered into suitable amalgamators, while the sludge or thin slime and surplus water run away to the waste dump. The consumption of water is no greater than in ordinary amalgamation.

It is a distinct feature of Fauvel's furnace, that the products of combustion from the fireplace (there is no smoke properly speaking) are from first to last kept away from contact with the ore. The passages E, provided for them are quite distinct, and are so arranged as to utilise all the heat generated, viz., in heating the shelves over which the ore runs, in maintaining the heat of all portions of the tower where it is needed, and in providing the supply of hot air. Finally, the products of combustion pass into the chimney L; near this chimney is a supplementary fireplace K, which may be used for generating chlorine gas, when dealing with silver ores, or to augment the draught.

The fumes of sulphur, arsenic, antimony, &c., generated by the heat encountered as the ore falls through the tower, flow upwards and become most dense on reaching the top of the tower.

This result is attained by the admission of a current of pure hot air at M, into the settling pit N at the bottom of the tower F. This air current serves the double purpose of aiding the oxidation, and conveying away the liberated fumes. These latter pass off at the top of the tower through an independent flue R, and on to a set of condensing chambers S, which are fitted with a series of exposed metal surfaces T, kept cold by a constantly renewed stream of water U. By these means, condensation of the sulphuric and other fumes is brought about in a rapid and effective manner, without contaminating the water. The result is a product which can be withdrawn simply and expeditiously by means of little trucks V made to run on rails O beneath the condensing chambers S. Thus the vapours admitted from the flues R through the condensing chambers S, into the chimney L, and finally escaping into the open air, are for the most part free from noxious properties.

It will be seen that Fauvel's invention, which has been patented all over the world, is not simply an improved furnace for roasting pyrites, but is actually a complete process for treating refractory gold ores. Its simplicity and economy will soon bring it into favour, and it will doubtless become familiarly known as "fauvelising."

WIRE ROPES (*continued from p. 80*).

*Uncoiling.*—It is most important to prevent kinking, that the coil should be placed on a reel or turn-table, and the rope drawn off from the outside.

*Attachments.*—With improved solid wrought-iron shoes or sockets for capping, no rivets are required; where the latter are employed, damage to the wires inside the socket is the result.

*Storing.*—Wire ropes should be kept in a dry place, and laid upon timbers. They should also be oiled over occasionally. Much damage often results from corrosion through improper storage.

*Preservation.*—When ropes are exposed to the destructive action of mineral or acid waters, they should be made of galvanised wires, and of as large a gauge as possible. In all cases a protection is afforded by frequently lubricating them with a good grease, free from creosote, ammonia, acids, or other injurious admixture. It is of especial importance that any broken wires should be cut away, or what is better, that they be bent backwards and forwards until they break off short at the place where they disappear into the rope, otherwise the broken wires, in consequence of the pressure, are apt to damage the neighbouring ones in passing over the drum and sheaves, and in this way whole strands in a partly-worn rope are often destroyed.

*Round Winding-rope Pulleys.*—The groove should be quite smooth and sufficiently wide, so as not to pinch the rope. The pulleys should be regularly inspected, and if it is found that the rope has been working a false groove into the pulley, the groove should be turned to its former shape, which can be done by fixing a cross-beam to serve as a rest for the turning tool. The false groove seldom harms the rope that has made it, but quickly damages the new rope which takes the old one's place, and which, not being worn, is of a larger diameter than the old rope, and does not fit into the false groove, therefore it the more rapidly wears on the sharp edges formed by the false groove with the original groove.

*Flat Winding-rope Drums and Pulleys.*—The drum arms or horns should be placed so far apart that the rope has not more than about  $\frac{1}{4}$  in. play between them. The inner edges of the horns should be well rounded off so as not to chafe the rope. The pulleys for flat ropes should have the grooves turned perfectly true and cylindrical, neither concave nor convex as belt pulleys are.

*Cable-laid Wire Ropes.*—These should be used where heavy weights have to be lifted occasionally, and where the winding barrel is necessarily of small diameter, such as for pit capstans, &c. As

*Cable-laid Wire Ropes*—continued.

they are not in constant use, it is essential that the wires should be galvanised so as to ensure the rope against the corrosive action of rust.

*Lang's Lay Wire Ropes.*—When wire ropes are constructed by the ordinary method, the friction surface is so comparatively small that the strands are worn only on the crowns. The wires retain their full size and strength at each side of the worn or weakened parts, causing them to give way, although the greater portion of the wires have been subjected to no wear whatever. In the construction of Lang's Lay ropes, there is a much larger wearing surface, which almost entirely removes the cause of the wires breaking on the crown of the strand, and as the working of the ropes around pulleys, drums, &c., bends the wires in an oblique direction, we secure by this system the greatest possible amount of wear from the wires before fracture, as they will not break before they are so much reduced in strength as to be too weak throughout for the work. The wires in the strands of the ropes on Lang's Lay principle have a very much longer bearing one against another than in the old system, and thereby prevent the great injury which results from the wires in the adjoining strands cutting into each other.

*Wire Driving Ropes.*—These are coming largely into use for transmission of power, and afford the cheapest means for this purpose for long or short distances. The loss of power amounts at the outside to 1 per cent. per 100 yd.

Table 148.—*Flat Wire*

Sizes.		Weights per fath.	Mild Steel (Siemens-Martin).			Improved Patent Steel.			Best Plough Steel.			Extra Plough Steel.			
Sizes.			Width.	Thick-ness.	Breaking strain.	Sizes.		Width.	Thick-ness.	Breaking strain.	Sizes.		Width.	Thick-ness.	Breaking strain.
Width.	Thickness.					Width.	Thick-ness.				Breaking strain.	Width.			
in.	in.	lb.	in.	in.	tons.	in.	in.	tons.	in.	in.	tons.	in.	in.	tons.	
2½	$\frac{7}{16}$	9	2½	$\frac{7}{16}$	15	2½	$\frac{7}{16}$	26	2½	$\frac{7}{16}$	33	2½	$\frac{7}{16}$	39	
2½	$\frac{1}{2}$	10	2½	$\frac{1}{2}$	17	2½	$\frac{1}{2}$	29	2½	$\frac{1}{2}$	36	2½	$\frac{1}{2}$	43	
2½	$\frac{5}{8}$	12	2½	$\frac{5}{8}$	20	2½	$\frac{5}{8}$	35	2½	$\frac{5}{8}$	44	2½	$\frac{5}{8}$	52	
2½	$\frac{3}{4}$	14	2½	$\frac{3}{4}$	23	2½	$\frac{3}{4}$	41	2½	$\frac{3}{4}$	51	2½	$\frac{3}{4}$	61	
3	$\frac{9}{16}$	16	3	$\frac{9}{16}$	27	3	$\frac{9}{16}$	47	3	$\frac{9}{16}$	59	3	$\frac{9}{16}$	70	
3½	$\frac{1}{2}$	18	3½	$\frac{1}{2}$	30	3½	$\frac{1}{2}$	53	3½	$\frac{1}{2}$	66	3½	$\frac{1}{2}$	79	
3½	$\frac{5}{8}$	20	3½	$\frac{5}{8}$	33	3½	$\frac{5}{8}$	59	3½	$\frac{5}{8}$	73	3½	$\frac{5}{8}$	88	
3½	$\frac{3}{4}$	23	3½	$\frac{3}{4}$	38	3½	$\frac{3}{4}$	68	3½	$\frac{3}{4}$	85	3½	$\frac{3}{4}$	102	
4	$\frac{7}{8}$	26	4	$\frac{7}{8}$	43	4	$\frac{7}{8}$	77	4	$\frac{7}{8}$	96	4	$\frac{7}{8}$	115	
4½	$\frac{1}{2}$	29	4½	$\frac{1}{2}$	48	4½	$\frac{1}{2}$	86	4½	$\frac{1}{2}$	108	4½	$\frac{1}{2}$	129	
4½	$\frac{5}{8}$	33	4½	$\frac{5}{8}$	53	4½	$\frac{5}{8}$	98	4½	$\frac{5}{8}$	123	4½	$\frac{5}{8}$	147	
4½	$\frac{3}{4}$	36	4½	$\frac{3}{4}$	60	4½	$\frac{3}{4}$	107	4½	$\frac{3}{4}$	134	4½	$\frac{3}{4}$	160	
5	1	39	5	1	65	5	1	116	5	1	145	5	1	174	
5½	$\frac{1}{2}$	44	5½	$\frac{1}{2}$	74	5½	$\frac{1}{2}$	131	5½	$\frac{1}{2}$	164	5½	$\frac{1}{2}$	196	
5½	$\frac{5}{8}$	48	5½	$\frac{5}{8}$	81	5½	$\frac{5}{8}$	143	5½	$\frac{5}{8}$	179	5½	$\frac{5}{8}$	214	
5½	$\frac{3}{4}$	52	5½	$\frac{3}{4}$	87	5½	$\frac{3}{4}$	155	5½	$\frac{3}{4}$	194	5½	$\frac{3}{4}$	232	
6	1½	57	6	1½	96	6	1½	170	6	1½	213	6	1½	255	

Note.—The weights per fathom for flat wire ropes are given for hemp core in each strand; for wire cores, add about  $\frac{1}{2}$  to the given weights.

Working Loads for Round and Flat Wire Ropes. For vertical winding at a

breaking strain. For hoisting, the working strain to gradient, and friction, &c., should be added.

Compound Round Wire Ropes, 2s. 6d. to 5s. per cwt. extra, according to the number of wires in the installation.

Table 149.—*Cage Guide Ropes or Conductors.*

Circumference, inches	..	3	3½	3½	3½	4	4½	4½	4½	5	5½	5½
Diameter, inches	..	$\frac{1}{2}$	$\frac{1}{2}$	$\frac{1}{2}$	$\frac{1}{2}$	$\frac{1}{2}$	$\frac{1}{2}$	$\frac{1}{2}$	$\frac{1}{2}$	$\frac{1}{2}$	$\frac{1}{2}$	$\frac{1}{2}$
Weight per fathom, lb.	..	11½	13½	15½	18½	21	23½	26½	29½	32½	36	39½

Table 150.—*Galvanised Wire Signal Strand.*

Number	..	00	0	1	2	3	4	5	6	7	8	9	10
Diameter, inches	..	$\frac{1}{2}$	$\frac{5}{16}$	$\frac{3}{8}$	$\frac{7}{16}$	$\frac{1}{2}$	$\frac{5}{8}$	$\frac{3}{4}$	$\frac{7}{8}$	$\frac{1}{2}$	$\frac{5}{8}$	$\frac{3}{4}$	$\frac{1}{2}$
7 Ply., W. G. No.	..	11	11½	12	13	13½	14	15	16	17	17½	18	18½
Length per cwt., yd.	..	150	170	190	240	280	310	380	480	640	750	850	1050

Table 151.—Round Wire Ropes.

Sizes.		Weights per Fathom.		Mild Steel (Siemens-Martin).		Improved Patent Steel.		Best Plough Steel.		Extra Plough Steel.	
Cir.	Dia.	6 Strands.		Cir.	Breaking Strain.	Cir.	Breaking Strain.	Cir.	Breaking Strain.	Cir.	Breaking Strain.
		7 Wires.	6 Wires.								
in.	in.	lb.	lb.	in.	tons.	in.	tons.	in.	tons.	in.	tons.
1	$\frac{3}{16}$	1.0	0.9	1	1½	1	2½	1	3½	1	4
1½	$\frac{1}{2}$	1.2	1.1	1½	2	1½	3½	1½	4½	1½	5½
1¾	$\frac{5}{16}$	1.5	1.3	1¾	2½	1¾	4½	1¾	5½	1¾	6½
1½	$\frac{3}{8}$	1.8	1.6	1½	3	1½	5½	1½	6½	1½	7½
1½	$\frac{7}{16}$	2.1	1.9	1½	3½	1½	6½	1½	7½	1½	9½
1½	$\frac{1}{2}$	2.5	2.3	1½	4	1½	7½	1½	9	1½	10½
1¾	$\frac{9}{16}$	2.9	2.6	1¾	4½	1¾	8½	1¾	10½	1¾	12½
1¾	$\frac{5}{8}$	3.3	3.0	1¾	5½	1¾	9½	1¾	11½	1¾	14½
2	$\frac{11}{16}$	3.8	3.5	2	6½	2	11	2	13½	2	16½
2½	$\frac{3}{4}$	4.3	4.0	2½	7	2½	12½	2½	15½	2½	18½
2½	$\frac{13}{16}$	4.8	4.4	2½	7½	2½	14	2½	17½	2½	21
2½	$\frac{7}{8}$	5.3	4.9	2½	8½	2½	15½	2½	19½	2½	22½
2½	$\frac{15}{16}$	5.9	5.5	2½	9½	2½	17½	2½	21½	2½	25½
2½	$\frac{1}{2}$	6.6	6.0	2½	10½	2½	19½	2½	24	2½	28½
2½	$\frac{17}{16}$	7.1	6.6	2½	11½	2½	20½	2½	25½	2½	31
2½	$\frac{19}{16}$	7.8	7.2	2½	12½	2½	22½	2½	28½	2½	34
3	$\frac{1}{2}$	8.5	7.8	3	14	3	25	3	31½	3	37½
3½	$\frac{11}{16}$	9.2	8.5	3½	15	3½	27	3½	33½	3½	40½
3½	$\frac{13}{16}$	9.9	9.1	3½	16½	3½	29	3½	36½	3½	43½
3½	$\frac{3}{4}$	10.7	9.9	3½	17½	3½	31½	3½	39½	3½	47½
3½	$\frac{15}{16}$	11.5	10.6	3½	19	3½	33½	3½	42	3½	50½
3½	$\frac{17}{16}$	12.3	11.4	3½	20½	3½	36	3½	45	3½	54
3½	$\frac{19}{16}$	13.2	12.2	3½	21½	3½	38½	3½	48½	3½	58
3½	$\frac{1}{2}$	14.1	13.0	3½	23½	3½	41½	3½	51½	3½	62½
4	$\frac{11}{16}$	15.0	13.9	4	24½	4	44	4	55	4	66
4½	$\frac{3}{4}$	16.0	14.8	4½	26½	4½	47	4½	58½	4½	70½
4½	$\frac{13}{16}$	17.0	15.7	4½	28½	4½	50	4½	62½	4½	75
4½	$\frac{7}{8}$	18.0	16.6	4½	29½	4½	53	4½	66½	4½	79½
4½	$\frac{15}{16}$	19.0	17.6	4½	31½	4½	56	4½	70	4½	84
4½	$\frac{17}{16}$	21.0	19.6	4½	35	4½	62½	4½	77½	4½	93½
4½	$\frac{19}{16}$	22.0	20.6	4½	36½	4½	64½	4½	80½	4½	96½
5	$\frac{1}{2}$	23.5	21.7	5	39	5	69	5	86½	5	103½
5½	$\frac{11}{16}$	26.0	24.0	5½	43	5½	76½	5½	95½	5½	114½
5½	$\frac{13}{16}$	28.5	26.3	5½	47	5½	83½	5½	104½	5½	125½
5½	$\frac{15}{16}$	31.1	28.7	5½	51½	5½	91½	5½	114½	5½	137½
6	$\frac{3}{4}$	34.0	31.3	6	56½	6	100	6	125	6	150

Note.—For wire core in centre of ropes, add  $\frac{1}{2}$  to the weights given for 6 strands of 7 wires.

Working Loads.—See remarks on p. 376.



## DRILLING (*continued from p. 124*).

### *The Ingersoll-Sergeant Rock Drill.*

The advantages of a combination of inventions are forcibly exemplified in the new Ingersoll-Sergeant Rock Drill. Until recently the Ingersoll drill and the Sergeant drill were manufactured by two separate companies, although the essential points in each drill had been designed by one man, Mr. Henry C. Sergeant. One of these drills, which he called the Eclipse, belonged to the Ingersoll Rock Drill Co., and the other, the later production, belonged to the Sergeant Drill Co. This machine embodied the results of an exceptionally long and varied experience in the manufacture of rock drills. It was, however, soon apparent, that to produce the most effective machine without infringement of patents, it would be necessary to amalgamate the two companies, and this being done, under the title of the Ingersoll-Sergeant Drill Co., a drill is now produced for which it may be justly claimed that it embraces in its design the best features of the older and the newer types of rock-drilling mechanism.

In order to introduce this machine into Great Britain and the continent of Europe, the Ingersoll-Sergeant Drill Co. has opened an office at 114A, Queen Victoria Street, London, where a stock of complete drills and duplicate parts is kept ready for use.

The object of the inventor has been to design a drill capable of striking a hard and effective blow and to construct it in such a way that it will resist the effects of rough work during long periods of use. The combination has also the further advantages obtained in simplicity and strength of construction, fewness of moving parts, and reduction of violent shocks to other parts than the piston. The new machine contains an independent valve operated through an auxiliary valve. This important point together with its great cutting capacity when used on hard rock have formed the two most distinctive features of the Sergeant drill, and they are now to be had in conjunction with the well-known and approved features of the Ingersoll. The Ingersoll-Sergeant strikes an uncushioned blow, and every blow that is struck is made with full pressure and with cylinder clear in front. This applies as much to the short quick strokes with which work may be commenced, as to the longer strokes when the drill is deeper in the rock. The auxiliary valve, which is operated by the shoulders of the piston, moves lightly in the arc of a circle, and cannot by any possibility become deranged, its wear being uniform and its action automatic, while in itself it is a

*Ingersoll-Sergeant Drill—continued.*

simple piece of steel of suitable shape, without any parts to break. The rotating device is equally simple and effective, and has a release movement, a feature we believe possessed by no other drill in the world, which prevents the twisting of the spiral bar, or breaking of pawls and ratchets; thus, when a hard blow is struck upon an uneven surface, there can be no danger of breaking through a tendency to rotate in the wrong direction; the springs, which are provided for cushioning the blow of the piston, being also made use of for controlling and assisting the rotation. There are other improvements comprising the ease with which long or short strokes are obtained by varying the feed; and the absence of stuffing boxes where compressed air is used is another important feature in this machine.

*The Ingersoll-Sergeant Cold Air Compressor.*

The latest improvement in air-compressing machinery is represented by the Ingersoll-Sergeant cold air compressor. No water is admitted in the air cylinder, but the most thorough cooling is effected by contact with cold metal surfaces. The piston inlet valve is operated by the natural laws of momentum and without springs or levers. The engine is driven either by steam, or through a belt or gearing by water power or electricity. The special advantages and most important features of the Ingersoll-Sergeant piston inlet cold air cylinder are as follow:—The free air, before admission to the cylinder, is under thorough control, and may be taken from that point which is the most favourable in its dryness, reduced temperature, and freedom from dust and other foreign matter. The admission of free air being through a single tube creates a constant and uniform draught of air in one direction only, thus filling the cylinder at each stroke with air at atmospheric pressure. The air inlet valves are large metallic rings which are not operated by springs, but which open and close by the natural momentum given to the valve by the movement of the piston. When the piston is moving in one direction, the ring valve on that face of the piston which is towards the direction of movement is closed, while that on the other face is open. This is exactly as it should be in order to discharge the compressed air from one end of the cylinder while taking in the free air at the other. The position of each valve is almost instantaneously reversed at the point when the stroke is reversed. This change in position takes place without springs or other influence than the natural momentum of a piece of metal which is carried in one direction and is instantly reversed.

The large ring air inlet valves which serve to admit the air are said to be practically indestructible. These valves admit of a large area of inlet with but a small throw of valve, thus quickly opening a large supply port, and enabling a compressor to run at high

*Cold Air Compressor*—continued.

speed without a reduction of efficiency, and with safety to the quick-moving parts. There being no inlet valves in the heads of the air cylinder, the space otherwise occupied by these valves is filled with cold water, thus presenting a cooling surface to the compressed air near the end of the stroke when the air is hottest. We have here all the advantages of cooling by water injection, without the disadvantages incident upon bad water, and the necessity of moving a body of water back and forth in the cylinder. Clearance spaces are reduced to a minimum. There are no countersunk spaces in the cylinder heads for inlet valves, but there is a single annular space to take the face of the large ring inlet valve. The valve covers this space at the end of each stroke so that there is no dead space. The air inlet pipe which extends through the cylinder-head serves as a bearing and support for the piston, thus ensuring the minimum wear in the air cylinder, and a perfect uniformity of such wear as must take place in every engine. This is said to be the only air compressor made with a device which unloads the engine automatically.

## RIVER MINING.

*Dredging (continued from p. 180).*

*Ball's Ejector Dredge for Mining Gold, Tin, Diamonds, &c., in rivers and placers.*

The most recent dredger bearing that name combines several of the features of the previous suction dredgers of the same builder (Charles Ball, C.E., 37, Lombard Street, E.C.), with some improvements which practice has shown to be essential.

The main features are :

1. That the material dredged does not go through the machinery as in ordinary suction dredgers, thereby saving all wear and tear caused by it, and enabling much coarser material and bigger stones to pass through a plant of a given size than was possible formerly.

2. That all compacted and hardened material is dug up and dispersed practically into the very nozzle of the suction apparatus—thereby preventing the loss of gold which occurs when it is attempted to stir up the material by rakes, revolving cutters, &c., in the current of a river, especially if at all rapid.

3. That it is assisted by an irresistible searcher, which goes right into cracks and fissures in the bed-rock, where often the gold is most thickly gathered, and pulls it out thereof to throw it into the suction nozzle—so that the loss of gold sometimes so great which occurs under these circumstances is entirely avoided.

4. The apparatus is even more simple than in the former Ball machines, and the cost and liability to repairs are both much diminished.

The results are obtained by the following means :—

A specially-built steam pump, worked from a small boiler, throws a stream of water, at very high pressure, into a dredging pipe in an ascending direction—this pipe is bent, after receiving this jet of water, so as to reach the bottom to be dredged—a branch, or several of them, got from where the high-pressure water enters the dredging-pipe, are brought in front of the nozzle on the ground, pre-ceeding it by a few inches.

These jets, under a head of some 300 ft. pressure or more, if required, tear up and rip the ground right into the nozzle, in which a violent sucking action is induced by the main jet entering above, as described previously.

These same small jets are the searchers which, with a flexibility that no machinery could possess, enter, ransack, and clear out of gold every crack and crevice in the bed-rock, even to a depth of several feet.

The material, with the water bringing it up, is delivered in a

## *Dredging—continued.*

gentle and regular stream at the top of the suction-pipe on to any sluice, or other preferred gold-saving apparatus.

The machinery can all be reduced to parts weighing under 120-lb., an immense advantage in case of difficulties of carriage. The cost of a plant capable of dealing with 4-in. stones, and doing some 10 tons of sand and gravels per hour, all complete, with improved and very efficient set of steel sluice boxes, is about 350*l.* to 400*l.*

A large plant on this system has lifted 2000 tons a day to large sluicing boxes.

It is essentially the machinery for prospecting on an efficient scale rivers, lagoons, &c.

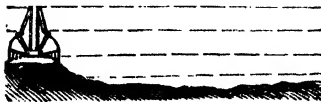
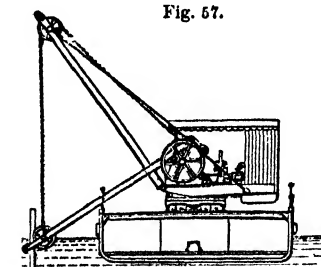
### *The "Cockburn" Dredger for Hard Materials.*

This machine has been designed by Cockburn, Phillips, and Montgomery, of 50, Queen Anne's Gate, Westminster, S.W., with the object of providing a crane dredger that will excavate material which the ordinary single and double chain grab dredgers will not touch.

In the ordinary form of crane dredger, the only force available for closing the grab is that which, if applied to a sufficient extent, will eventually raise it off the ground, and consequently its resistance to being lifted—*i.e.*, its dead weight—is the utmost limit of the closing power that can be applied.

It is obvious that the harder the material to be dredged, the greater the pull required on the chain to close the grab, and as the pull on the chain increases, so the weight of the grab on the ground will decrease. Thus there is less available weight to cause the grab to penetrate in dealing with hard material than there would be with soft.

In the dredger shown in Fig. 57, an arrangement is provided by which the force applied for closing the grab does not tend to raise it off the ground; consequently, when the grab is dropped, and the points or blades sink several inches into the ground, any requisite



"Cockburn" Dredger.

amount of force can be applied to close the jaws on the material without the possibility of the jaws slipping up, and merely scraping

*Dredging—continued.*

over the top of the ground. It is therefore plain that this dredger will excavate any material into which the points or blades of the jaws will sink several inches when the grab is dropped into it.

As the grabs weigh from 35 cwt. to 55 cwt., according to size, it is not difficult to form an idea of the immense hardness that material would have to possess before this dredger would fail to excavate it.

The closing of the grab is effected by a chain secured to the top of the tube, led under a guide pulley to the jib head, round a snatch block or monkey, over a second guide pulley, and finally taken round and secured to an ordinary windlass barrel in the grab frame. A chain is attached to the snatch block or monkey, and led to the derrick barrel of the crane. When this barrel is revolved, the grab is opened or closed at will in any position.

In dredging cranes which are fitted with a long pole or tube fixed into the grab, and working through the head of the crane jib, the depth to which the dredger will work is limited by the greatest length of pole or tube that can be used in practice with safety and consistently with its strength as a column. This limit is reached in a pole or tube about 30 ft. in length, so that, allowing the jib head of a crane dredger to be 18 ft. above water line, and the total length of pole and grab to be 35 ft., the limit is reached at 15 ft. dredge.

To provide against this, a movable or falling jib is pivoted to the frame of the crane, carrying the two guide sheaves for the closing chain at its outer end. By this means a depth of 32 ft. below water line can be reached with a length of pole or tube well within the range of practice.

An additional advantage is obtained from the falling jib in the case of dredging where either waves or a swell are to be met with. The movable jib forms a hinged connection between the grab and the crane, so that any rise or fall of the barge carrying the dredger is taken up by the movable jib, and does not affect the grab, nor interfere with the closing of it.

The illustration is from a machine arranged to dredge to a depth of 25 ft., and manufactured by Grafton and Co., of Bedford, for the patentees.

The machine is made in two sizes :

$\frac{3}{4}$ yd. grab	and 7 ton crane	to dredge to 25 ft.
1 " "	10 " "	32 ft.

For depth of dredge to 15 ft. the falling jib is not required.

Prices:—

To excavate 450 tons of hard material a day ..	..	775/.
" 600 " " "	..	950/.

## ORE DRESSING.

(Continued from p. 187.)

IN order to obtain the most satisfactory results in dressing ores, great care must be taken in adapting the arrangement of machinery to the requirements of each case, and in carefully selecting the most suitable machines.

By following out a system of continuous concentration, aided by improved labour-saving appliances, particularly in the slimes department, and by observing suitable methods for minimising the production of slimes in crushing and separating, better results are obtained with less waste, and the cost of dressing is greatly decreased in all cases.

*Lührig's Compound Vanner.*

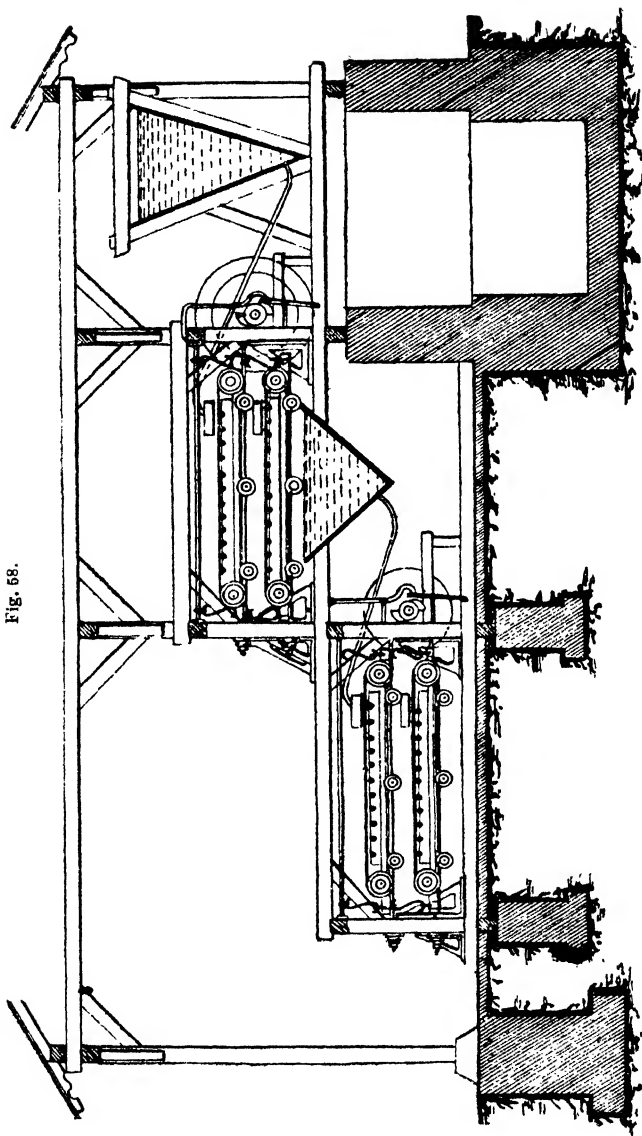
Quite remarkable, among the various recent improvements in ore-dressing plant, is the "Compound Vanner," invented by Lührig, whose success in coal-cleaning machinery is familiar. This novel vanner demands special mention for its self-acting qualities, and for its very successful treatment of slimes of the most complex character.

The striking feature of the Lührig vanner, as will be seen by Fig. 58, is the combination of three, four, or six (according to the nature of the ore) single tables of an improved construction, arranged in such a way as to allow of automatically feeding the "middle products" (or not yet sufficiently clean products) from the upper tables on to the lower tables. By this subsequent treatment of the middle products on the same machine, high concentrates are obtained without requiring manual labour or incurring loss of mineral.

The single table consists in the main of a travelling band, with adjustable lateral inclination, suspended from a frame receiving an end-shake, which, combined with the action of a spray-pipe extending diagonally across the table, effects the separation of the various minerals in the pulp, according to their specific weights. These various products are washed off by the spray into receptacles in front of the table. The material is fed on to the table by a siphon discharge from a hydraulic classifier.

The advantages of the single table over others consist, firstly, in the circumstance that *one* clean product is always obtained in one operation; and, secondly, any number of grades of concentrates of different ores may be obtained on one table, and the degree of concentration, as well as the percentage of mineral left in the tailings, be adjusted according to wish. The intermediate grades

Fig. 68.



Lathrig's Compound Vanner.



*Lühhig's Compound Vanner*—continued.

would then be made to yield higher concentrates by the lower tables of the compound vanner, as described before.

One compound vanner will treat about 9 tons per day of 10 hours, giving absolutely clean tailings, besides separating the various minerals contained in the ore, one from the other. It has been proved to give excellent results in treating slimes of lead and blende ores containing iron or copper pyrites, or spathic iron; and it is particularly well adapted for dealing with tin and copper ores, avoiding all the handling now so frequently necessary in consequence of the use of imperfect machines, such as buddles, &c.

In dressing auriferous ores containing a percentage of pyrites, this vanner does closer work with less cost than any other machine, and it has been proved that it will pay well in many cases to employ it on old tailings containing less than 4 dwt. of gold and 4 dwt. of silver to the ton.

The manufacture and sale of these machines in England, America, and the Colonies are in the hands of the Lühhig Coal and Ore Dressing Appliances, Limited, 32, Victoria Street, Westminster, S.W.

## GLOSSARY.

- Abattis* (Leicester), cross packing of branches or rough wood, to keep roads open for ventilation.
- Abbruch* (Germ.), ore broken off the vein.
- Abendort* (Germ.), western end of a mine.
- Abendschicht* (Germ.), afternoon shift.
- Abendstoss* (Germ.), western end of a mine
- Abfenherd* (Germ.), buddle.
- Abfüllen* (Germ.), to win a good body of ore.
- Abkommiss* (Germ.), junction of main lode and tributary.
- Ahra* (Span.), fissure in a lode.
- Abronzado* (Span.), copper sulphides.
- Abstrich* (Germ.), the mass of black litharge appearing on the bath of work-lead early in cupelling.
- Abtheilung* (Germ.), a defined district of a mine under care of a deputy.
- Abzug* (Germ.), the first scum appearing (before *abstrich*) on molten lead.
- Accompt* (Corn.), settling day or place.
- Achicar* (Span.), to decrease water in a mine.
- Acreage rent* (Eng.), royalty or rent for working minerals.
- Addings* (N. Eng.), earnings.
- Ademar* (Span.), to timber.
- Ademador* (Span.), mine carpenter.
- Adit*, a slightly rising tunnel driven into a mine from daylight, and used for access, transport, and drainage.
- Adobe* (Span.), sun-dried brick.
- Adventurers*, original prospectors.
- After-damp*, poisonous gas resulting from explosions of fire-damp chiefly carbonic acid.
- Agitator* (W. Amer.), settler.
- Ahondar* (Span.), to sink.
- Air-box*, wooden tubes, 9-15 ft. long, for ventilating headings or sinkings.
- Air-course*, ventilation channels.
- Air-crossing*, a bridge carrying one air-course across another
- Air-end way*, ventilation levels run parallel with main level.
- Air-gate* (Midlands), ventilation ways.
- Air-head* (Staff.), ventilation ways.
- Airless end*, unventilated extremity of a stall in long-wall workings.
- Air-level*, an old level used for ventilating.
- Air-slit* (Yorks.), a short head between other air-heads.
- Air-stuck*, ventilating chimney.

- Aitch-piece*, parts of a pump in which the valves are fixed.  
*Alb cñil* (Span.), mason.  
*Albayalde* (Span.), white lead.  
*Alberti furnace*, a continuous reverberatory for mercury ores.  
*Alcam* (Wales), tin.  
*Aline* (Corn.), productive.  
*Alligator* (Amer.), rock breaker.  
*Alloy*, compound metal.  
*Alluvium*, gravel, sand, and mud deposited by streams.  
*Almadeneta* (Span.), stamp-head.  
*Almagre* (Span.), red ochre.  
*Aludel* (Span.), earthen condenser for mercury.  
*Amalgamation*, absorption of gold and silver by mercury.  
*Anemometer*, wind measurer.  
*Anthracite*, hard, very pure coal.  
*Apex* (Amer.), end or edge of vein nearest surface.  
*Apolvillados* (Span.), superior ores.  
*Appolt oven*, a coke oven.  
*Aprons* (Amer.), battery copper plates.  
*Arch* (Corn.), portion of lode left standing to support hanging wall, or because too poor.  
*Arenaceous*, sandy.  
*Arends tip*, an inverted siphon for drawing molten lead from crucible or furnace.  
*Arenillos* (Span.), refuse earth.  
*Argentiferous*, silver-bearing.  
*Argillaceous*, clayey.  
*Arian* (Wales), silver.  
*Arm*, the inclined leg of a set of timber.  
*Arrage* (N. Eng.), sharp corner.  
*Arrastra* (Span.), an amalgamating mill.  
 — *de cuchara* (—), spoon arrastra.  
 — *de marca* (—), large arrastra.  
 — *de mula* (—), mule-power arrastra.  
*Arrastrar* (Span.), union of veins.  
*Aspirail* (Fr.), opening for ventilation.  
*Assessment work* (W. Amer.), the annual work necessary to hold a claim.  
*Atel*, overhead boarding in a gallery.  
*Astyllen* (Corn.), small dam in an adit; partition between ore and deads on grass.  
*Atierres* (Span.), refuse rock.  
*Atizador* (Span.), furnace man.  
*Attle* (Corn.), refuse rock.  
*Auger-stem*, bar to which a drilling bit is attached.  
*Auget*, priming tube.  
*Aur* (Wales), gold.  
*Auriferous*, gold-bearing.  
*Ausscharen* (Germ.), junction of lodes.

*Auszimmern* (Germ.), timbering.

*Average produce* (Corn.), percentage of fine copper in ore.

*Average standard* (Corn.), price of pure copper in ore.

*Aviador* (Span.), he who provides the capital to work a mine.

*Azogue* (Span.), mercury.

*Azoquero* (Span.), amalgamating works.

*Azoquero* (Span.), amalgamator.

*Azoques* (Span.), inferior ores.

*Back* (Corn.), lode lying between adit and surface.

*Back-casing*, temporary shaft-lining of dry-laid bricks.

*Back-end* (N. Eng.), the last portion of a judd.

*Backing*, timbers let into notches in the rock across the top of a level.

*Backing deals* (N. Eng.), vertical planks behind the curbs in a shaft.

*Back-shift*, afternoon shift.

*Back-skin* (N. Eng.), a leather jacket for wet workings.

*Bail*, provisions.

*Bal* (Corn.), a mine.

*Balance-bob*, a heavy counterpoise to pump-rods.

*Balk* (N. Eng.), a hitch causing a nip.

*Balland* (Derb.), pulverulent lead ore.

*Bancos* (Span.), rocks disturbing a lode.

*Band* (N. Eng.), stone interstratified with coal.

*Bank*, (1) surface at pit's mouth; (2) deposit worked above water level; (3) coal face.

*Bank claim* (Aust.), mining right on bank of stream.

*Bank right* (Aust.), right to divert water to bank claim.

*Baño* (Span.), excess of mercury used in torta.

*Bar*, (1) ridge crossing lode or stream; (2) drilling-rod.

*Bar diggings* (W. Amer.), auriferous claims on shallow stream.

*Bargain*, portion of mine worked by a gang on contract.

*Barilla* (Span.), grains of native copper disseminated through ores.

*Barnmaster* (Derb.), mine manager, agent, and engineer.

*Barmote* (Derb.), mining court.

*Barrel-work* (N. Amer.), native copper that can be hand-sorted ready for smelting.

*Borrow* (Corn.), a dump.

*Basque*, crucible or furnace lining.

*Bass* (Derb.), indurated clay.

*Basset*, an outcrop.

*Batea* (Span.), a bowl for separating metal from refuse.

*Batt* (Derb.), indurated clay.

*Beams* (N. Eng.), small coals.

*Beam-shot*, copper granulated by pouring into hot water.

*Beat* (Corn.), to cut away a lode.

*Bed-claim* (Aust.), a mining-claim on bed of stream.

*Bed-rock*, solid rock underlying alluvial.

*Bede*, miners' pickaxe.

*Belly-helce*, forge hammer lifted by cam.

*Ben* (Corn.), productive.

*Benching up* (N. Eng.), working on top of coal.

*Bend* (Derb.), indurated clay.

*Benhoyl* (Corn.), flowing tin stream.

*Biche*, a hollow-ended tool for recovering boring rods.

*Bind* (Derb.), indurated clay.

*Binder* (Corn.), mine carpenter.

*Bing* (N. Eng.), 8 cwt. of ore.

*Bing-hole* (Derb.), an ore-shoot.

*Bing-ore* (Derb.), lead ore in lumps.

*Bing-iale* (N. Eng.), ore given to the miner for his labour.

*Black band*, an earthy carbonate of iron found in coal-beds.

*Black copper*, impure smelted copper.

*Black dump*, carbonic acid gas.

*Black ends*, refuse coke.

*Black flux*, charcoal and potassium carbonate.

*Black jack*, zinc blende.

*Black lead*, graphite.

*Black sand* (Aust.), dark minerals found with alluvial gold.

*Black tin* (Corn.), dressed tin ore.

*Blanch*, lead ore mixed with other minerals.

*Blanché copper*, copper alloyed with arsenic.

*Blanket strake* (Aust.), sloping tables or sluices lined with baize for catching gold.

*Blick* (Germ.), iridescence on gold and silver at end of cupelling.

*Blind creek* (Aust.), dry watercourse.

*Blind level*, (1) an incomplete level; (2) a drainage level.

*Bloat*, a hammer swelled at the eye.

*Block claim* (Aust.), a square mining claim.

*Block tin*, cast tin.

*Blocking out* (Aust.), washing gold gravel in sections.

*Bloemary*, a forge for making wrought iron.

*Blossom*, the decomposed outcrop of a vein or coal-bed.

*Blower* (N. Eng.), an outrush of gas.

*Blue-billy*, residue of copper pyrites after roasting with salt.

*Blue elvan* (Corn.), greenstone.

*Blue-john* (Derb.), fluorspar.

*Blue lead* (W. Amer.), a blue-stained stratum of gravel of great extent and richness.

*Blue peach* (Corn.), a slate-blue fine-grained schorl.

*Blue stone*, copper sulphate.

*Bob* (Corn.), triangular frame transmitting power from engine to pump-rods.

*Boca* (Span.), mine mouth.

*Bocamina* (Span.), mine mouth.

*Bay iron ore*, loose earthy brown hematite recently formed in swampy ground.

- Bollos* (Span.), triangular blocks of amalgam.  
*Bolsa* (Span.), small bunch of ore.  
*Bonanza* (Span.), body of rich ore.  
*Bone*, slaty matter in coal seams.  
*Bonnet*, the roof of a cage.  
*Bonney* (Corn.), an isolated body of ore.  
*Bonze*, undressed lead ore.  
*Booming*, removing gravel by sudden outlets of pent-up water.  
*Borrascu* (Span.), unprofitable ore.  
*Bort*, amorphous dark diamond.  
*Bottoms*, impure copper alloy below the matt in smelting.  
*Bounds* (Corn.), a tract of tin ground.  
*Bout* (Derb.), 24 dishes of lead ore.  
*Box* (Staff.), small wooden box for hauling ironstone underground  
*Bourse* (Derb.), lead ore as cut from the lode.  
*Box-bill*, tool for recovering boring-rods.  
*Brace* (Corn.), buildings at pit mouth.  
*Braize* (Amer.) charcoal dust.  
*Brake-siere*, hand jigger.  
*Brances*, iron pyrites in coal.  
*Branch*, small vein shooting off from main lode.  
*Brasses*, iron pyrites in coal.  
*Brat*, a thin bed of coal mixed with pyrites or limestone.  
*Brattice*, a lining or partition.  
*Brazil* (N. Eng.), iron pyrites in coal.  
*Breeze*, small coke.  
*Brettis* (Derb.), a timber crib filled with slack.  
*Broaching bit*, a tool for re-opening bore-hole which has partially closed by swelling of the walls.  
*Brob*, a spike to prevent timber slipping.  
*Broil* (Corn.), traces of a vein in loose matter.  
*Brooch* (Corn.), mixed ores.  
*Brood* (Corn.), heavy waste from tin and copper ores.  
*Brownspar*, ferruginous dolomite.  
*Browse*, imperfectly smelted ore mixed with cinder and clay.  
*Bryle* (Corn.), traces of a vein in loose matter.  
*Bucking*, breaking down ore with a very broad hammer ready for jiggling.  
*Buddle*, an inclined stationary or revolving platform, on which ores are dressed.  
*Buitron* (Span.), a silver furnace.  
*Bulkhead*, (1) a tight partition, or stopping; (2) the end of a flume carrying water for hydraulicing.  
*Bulldog*, furnace lining.  
*Bully*, a miners' hammer.  
*Bunch*, a small rich ore body.  
*Bunding*, a staging in a level for carrying debris.  
*Bunney*, a nest of ore not lying in a regular vein.  
*Burden*, earth overlying a bed of useful mineral.

*Belly-helve*, forge hammer lifted by cam.

*Ben* (Corn.), productive.

*Benching up* (N. Eng.), working on top of coal.

*Benl* (Derb.), indurated clay.

*Benheyl* (Corn.), flowing tin stream.

*Biche*, a hollow-ended tool for recovering boring rods.

*Bind* (Derb.), indurated clay.

*Binder* (Corn.), mine carpenter.

*Bing* (N. Eng.), 8 cwt. of ore.

*Bing-hole* (Derb.), an ore-shoot.

*Bing-ore* (Derb.), lead ore in lumps.

*Bing-tale* (N. Eng.), ore given to the miner for his labour.

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*Black dump*, carbonic acid gas.

*Black ends*, refuse coke.

*Black flux*, charcoal and potassium carbonate.

*Black jack*, zinc blende.

*Black lead*, graphite.

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*Black tin* (Corn.), dressed tin ore.

*Blanch*, lead ore mixed with other minerals.

*Blanched copper*, copper alloyed with arsenic.

*Blanket stroke* (Aust.), sloping tables or sluices lined with baize for catching gold.

*Blick* (Germ.), iridescence on gold and silver at end of cupelling.

*Blind creek* (Aust.), dry watercourse.

*Blind level*, (1) an incomplete level; (2) a drainage level.

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*Block tin*, cast tin.

*Blocking out* (Aust.), washing gold gravel in sections.

*Bloomary*, a forge for making wrought iron.

*Blossom*, the decomposed outcrop of a vein or coal-bed.

*Blower* (N. Eng.), an outrush of gas.

*Blue-billy*, residue of copper pyrites after roasting with salt.

*Blue elvan* (Corn.), greenstone.

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*Blue lead* (W. Amer.), a blue-stained stratum of gravel of great extent and richness.

*Blue peach* (Corn.), a slate-blue fine-grained schorl.

*Blue stone*, copper sulphate.

*Bob* (Corn.), triangular frame transmitting power from engine to pump-rods.

*Boca* (Span.), mine mouth.

*Boconna* (Span.), mine mouth.

*Bog iron ore*, loose earthy brown hematite recently formed in swampy ground.

*Boliche* (Span.), concentrating bowl.

- Bollos* (Span.), triangular blocks of amalgam.  
*Bolsa* (Span.), small bunch of ore.  
*Bonanza* (Span.), body of rich ore.  
*Bone*, slaty matter in coal seams.  
*Bonnet*, the roof of a cage.  
*Bonney* (Corn.), an isolated body of ore.  
*Bonze*, undressed lead ore.  
*Booming*, removing gravel by sudden outlets of pent-up water.  
*Borrasca* (Span.), unprofitable ore.  
*Bort*, amorphous dark diamond.  
*Bottoms*, impure copper alloy below the matt in smelting.  
*Bonads* (Corn.), a tract of tin ground.  
*Bout* (Derb.), 24 dishes of lead ore.  
*Bowke* (Staff.), small wooden box for hauling ironstone underground  
*Bowse* (Derb.), lead ore as cut from the lode.  
*Box-bill*, tool for recovering boring-rods.  
*Brace* (Corn.), buildings at pit mouth.  
*Braize* (Amer.) charcoal dust.  
*Brake-sieve*, hand jigger.  
*Branches*, iron pyrites in coal.  
*Branch*, small vein shooting off from main lode.  
*Brasses*, iron pyrites in coal.  
*Brat*, a thin bed of coal mixed with pyrites or limestone.  
*Brattice*, a lining or partition.  
*Brazil* (N. Eng.), iron pyrites in coal.  
*Breeze*, small coke.  
*Brettis* (Derb.), a timber crib filled with slack.  
*Broaching bit*, a tool for re-opening bore-hole which has partially closed by swelling of the walls.  
*Brob*, a spike to prevent timber slipping.  
*Broil* (Corn.), traces of a vein in loose matter.  
*Brooch* (Corn.), mixed ores.  
*Brood* (Corn.), heavy waste from tin and copper ores.  
*Brownspar*, ferruginous dolomite.  
*Browse*, imperfectly smelted ore mixed with cinder and clay.  
*Bryle* (Corn.), traces of a vein in loose matter.  
*Bucking*, breaking down ore with a very broad hammer ready for jiggling.  
*Buddle*, an inclined stationary or revolving platform, on which ores are dressed.  
*Buitron* (Span.), a silver furnace.  
*Bulkhead*, (1) a tight partition, or stopping; (2) the end of a flume carrying water for hydraulicing.  
*Bulldog*, furnace lining.  
*Bully*, a miners' hammer.  
*Bunch*, a small rich ore body.  
*Bunding*, a staging in a level for carrying débris.  
*Bunney*, a nest of ore not lying in a regular vein.  
*Burden*, earth overlying a bed of useful mineral.



*Burr*, solid rock.

*Burrow*, refuse heap.

*Buscones* (Span.), prospectors, fossickers, tribute workers.

*Butt*, coal surface exposed at right angles to the face.

*Butty* (Mid.), a contract miner.

*Cabezuela* (Span.), rich gold and silver concentrates.

*Cal* (Corn.), wolfram.

*Cala* (Span.), prospecting pit.

*Caliche* (Span.), felspar.

*Callys* (Corn.), stratified rocks traversed by lodes.

*Canch*, stone quarry.

*Cancha* (Span.), space for drying slimes.

*Cand* (Corn.), fluorspar.

*Cank* (Derb.), whinstone.

*Caple* (Corn.), hard rock lining tin lodes.

*Carbona* (Corn.), an irregular deposit of tin ore.

*Case*, a fissure admitting water into a mine.

*Cata* (Span.), a mine denounced but not worked.

*Cauf* (N. Eng.), a coal bucket or basket.

*Caunter* (Corn.), a vein crossing diagonally.

*Cawk*, baryta sulphate.

*Cazeador* (Span.), amalgamator.

*Chats* (N. Eng.), small pieces of stone with ore.

*Chilian mill*, a mortar mill.

*Chimney*, an ore shoot.

*Choke-dump*, carbonic acid gas.

*Chuzu* (Span.), a washer.

*Claggy* (N. Eng.), when coal is tightly joined to the roof.

*Claim*, a portion of mining ground held under one grant.

*Clean-up*, collecting the product of a period of work with battery or sluice.

*Cleat*, (1) a joint in rock ; (2) a wedge.

*Clod*, soft shale or slate roof to coal.

*Coal-pipes* (N. Eng.) very thin irregular coal beds.

*Cob* (Corn.), to break up ore for sorting.

*Cobre*, Cuban copper ores.

*Cockle* (Corn.), black tourmaline, often mistaken for tin.

*Cod* (N. Eng.), the bearing of an axle.

*Cofer* (Derb.), to caulk a shaft by ramming clay behind the lining.

*Coffer*, the iron box in which stamps work.

*Coffin* (Corn.), an old pit.

*Coil drag*, a tool for picking pebbles, &c., from drill holes.

*Colas* (Span.), brown sulphides.

*Colorados* (Span.), decomposed ores stained with iron.

*Colours*, particles of gold found in panning a sample.

*Colrake*, a shovel for stirring lead ores while washing.

*Cope* (Derb.), lead mining on contract.

*Copela* (Span.), dry amalgam.

*Copelilla* (Span.), zinc-bende.

*Corbond*, an irregular mass from a lode.

*Corf*, a mine wagon or tub.

*Coro-coro* (S. Amer.), grains of native copper mixed with pyrite, chalcoppyrite, mispickel, &c.

*Corve*, a mining wagon or tub.

*Cost-book* (Corn.), mining accounts.

*Costean* (Corn.), to prospect a lode by sinking pits on its supposed course.

*Country*, the formation traversed by a lode.

*Cow*, a self-acting brake.

*Coyotiny* (W. Amer.), irregular mining by small pits.

*Crab-hole* (Aust.), water-worn holes in bed rock.

*Cradle*, a wooden trough for washing gold sands.

*Cramp*, a pillar left for support in a mine.

*Cranch*, part of a vein left by previous workers.

*Creaze* (Corn.), tin ore collected in the middle of the buddle.

*Creep*, movement of walls or floor of a mine.

*Crib*, a timber frame.

*Cribble*, a sieve.

*Crop* (Corn.), the richest portion of dressed tin ore.

*Cross-course*, a cross vein.

*Cross-cut*, a level driven across a vein.

*Crosses and holes* (Derb.), made in the ground by the discoverer of a lode to temporarily secure possession.

*Croic-foot*, a tool for drawing broken boring rods.

*Cubn* (Eng.), anthracite; (N. Amer.), fine waste coal and dirt.

*Curb*, a timber frame.

*Dam*, a barrier for water or gases.

*Damp*, poisonous gas.

*Dan* (N. Eng.), a truck without wheels.

*Dant* (N. Eng.), soft inferior coal.

*Dead*, (1) unproductive; (2) unventilated.

*Dead men's graves* (Aust.), grave-like mounds in the basalt underlying auriferous gravels.

*Dead riches* (N. Amer.), lead carrying much bullion.

*Dead roasting*, roasting till all sulphur is driven off.

*Deads*, rubbish.

*Dead work*, unproductive work.

*Dean* (Corn.), the end of a level.

*Desaguator* (Span.) a water pipe or drain.

*Desecho* (Span.), floured mercury.

*Desmontes* (Span.), poor ores.

*Despoblado* (Span.), ore with much gangue.

*Dessue* (Corn.), to cut away the ground beside a thin vein so as to remove the latter whole.

*Dialling*, surveying.

*Dillueing* (Corn.), dressing tin slimes in a fine sieve.

*Dippa* (Corn.), a small catch-water pit.

*Dish* (Corn.), an ore measure; in lead mines a trough 28 in. long, 4 in. deep, and 6 in. broad; sometimes 1 gal., sometimes 14-16 pints.

*Dizzue* (Corn.), see *Dessue*.

*Dolly*, (1) a perforated board for breaking up clay in puddling;

(2) a primitive quartz stamp.

*Donk* (N. Eng.), soft mineral found in cross veins.

*Dradge* (Corn.), inferior ore separated from the prill.

*Dresser* (Staff.), a large coal pick.

*Drift*, (1) a tunnel following the vein; (2) alluvial deposits.

*Dropper*, a branch leaving the vein on the footwall side.

*Druggon* (Staff.), a vessel for carrying fresh water into a mine.

*Dunb'd*, choked—of a sieve or grating.

*Dunp*, a heap of ore or refuse.

*Durn* (Corn.), a timber frame.

*Dürr* (Germ.), barren ground.

*Dzhu* (Corn.), see *Dessue*.

*Efydd* (Wales), copper.

*Elvan* (Corn.), a belt of felspathic or porphyritic rock.

*Estano* (Span.), tin.

*Fahlband* (Germ.), a course impregnated with metallic sulphides.

*Faiscutor* (Span.), a gold-washer.

*False bottom*, a bed of rock under alluvial which has other alluvial below it.

*Famp* (N. Eng.), thin beds of soft tough shale.

*Fang* (Derb.), an air course.

*Fast* (Corn.), bedrock.

*Feigh* (N. Eng.), ore refuse.

*Ferro blanco* (Span.), arsenopyrite.

*Flang* (Corn.), a double-pointed pick.

*Flat wall* (Corn.), footwall.

*Float*, detached fragments of a quartz reef.

*Floran* (Corn.), very fine tin.

*Flouring*, the breaking-up and contamination of mercury, rendering it useless for amalgamating.

*Flucan* (Corn.), clayey matter in a lode.

*Fluke*, a rod for cleaning out drill-holes.

*Flume*, a water conduit.

*Fluthwerk* (Germ.), river prospecting.

*Fodder* (N. Eng.), 21 cwt. of lead.

*Foot* (Corn.), 2 gal. or 60 lb. black tin.

*Force piece*, diagonal timbering to secure the ground.

*Fork* (Corn.), bottom of sump; (Derb.), prop for soft ground.

*Fossicking*, casual and unsystematic mining.

*Fother* (N. Eng.),  $\frac{1}{3}$  chaldron.

*Free milling*, ores requiring no roasting or chemical treatment.

*Gad*, a wedge.

*Gal* (Corn.), hard gossan.

*Gale*, a grant of mining ground.

*Galeador* (Span.), a silver furnace.

*Galiage*, royalty.

*Gangue*, refuse associated with ore.

*Ganister*, furnace lining composed of fire clay and ground quartz.

*Gatches* (Corn.), final sludge from tin dressing.

*Glist* (Corn.), micaceous iron ore.

*Goaf*, worked-out ground, and the refuse with which it is filled.

*Gob*, see *Gouf*.

*Gossan* (Corn.), ferruginous quartz or calcespar filling a lode.

*Gottis* (Staff.), sudden burstings of coal from the face owing to tension caused by unequal pressure.

*Gouge* (N. Amer.), soft clay lying between the ore body and sides of the lode.

*Grass*, surface.

*Grassero* (Span.), slag-heap.

*Grenut* (Span.), undressed ore.

*Grizzly* (W. Amer.), a grating to throw out large stones from hydraulic gold sluices.

*Groove* (Derb.), a mine.

*Grouan* (Corn.), granite.

*Grundy*, granulated pig iron.

*Gwy* (Corn.), worked-out ground.

*Gubbin*, ironstone.

*Guija* (Span.), quartz.

*Gunnies* (Corn.), 3 ft.

*Gurt* (Corn.), water runnel from dressing-floor.

*Haiwn* (Wales), iron.

*Halvans* (Corn.), inferior copper ore.

*Hard-head*, residue from tin refining; contains much iron and arsenic.

*Hazle* (N. Eng.), sandstone mixed with shale.

*Hechudo* (Span.), dip.

*Hilo* (Span.), a thin metalliferous vein.

*Hulk* (Corn.), to pick out the soft portions of a lode.

*Hungry*, worthless looking.

*Hushing*, prospecting by laying ground bare by sudden discharges of pent-up water.

*Hutch* (Corn.), an ore-washing box.

*Hydraulicity* (W. Amer.), working auriferous gravel beds by hydraulic power.

*Inch*, *Miners'*, see p. 23.

*Irestone* (Corn.), any hard tough stone.

*Iron hat*, decomposed ferruginous mineral capping a lode.

*Itabirite* (Braz.), micaceous iron ore.

*Jacotinga* (Braz.), ferruginous ores associated with gold.

*Jales* (Span.), tailings.

*Jigging*, separating heavy from light particles by agitation in water.

*Judge* (Derb. and N. Eng.), a measuring staff.

*Kann* (Corn.), fluorspar.

*Kazen* (Corn.), a sieve.

*Keckle-meckle*, poorest lead ore.

*Kerned* (Corn.), pyrites hardened by exposure.

*Keril* (Derb.), a calcspar found in lead veins.

*Kibble*, a mining bucket.

*Kieve*, tossing-tub.

*Killas* (Corn.), clay slate.

*Kircking* (N. Eng.), the cutting made beneath the coal seam.

*Lama* (Span.), slimes.

*Lappior* (Corn.), an ore dresser.

*Launder*, water trough.

*Lazyback* (Staff.), a coal stack.

*Leat*, water-course.

*Leavings* (Corn.), halvans.

*Limadura de plati* (Span.), dry silver amalgam.

*Linnets* (Derb.), oxidised lead ores.

*Lista* (Span.), tail of impure mercury.

*Long-ton*, a gold-washing trough.

*Loob* (Corn.), sludge from tin dressing.

*Macizo* (Span.), unworked lode.

*Magistral* (Span.), roasted copper pyrites, copper sulphate, &c., used to reduce silver ores.

*Makings* (N. Eng.), small coal produced in kirving.

*Manga* (Span.), canvas bag for straining amalgam.

*Maquilla* (Span.), a custom mill.

*Murmajus* (Span.), concentrated sulphides.

*Maza* (Span.), stamp head.

*Mear* (Derb.), 32 yd. along the vein.

*Miners' inch*, see p. 23.

*Mistress* (N. Eng.), a miners' lamp.

*Mock-lead* (Corn.), zinc-blende.

*Moil* (Corn.), a wedge-pointed drill.

*Mucks* (Staff.), bad earthy coal.

*Mundic*, pyrites.

*Negrillo* (Span.), black sulphide of silver.

*Nittings*, refuse of good ore.

*Noria* (Span.), an endless chain of buckets.

*Nuts*, coal of a certain size.

*Oro* (Span.), gold.

*Oroche* (Span.), retorted bullion.

*Overburden*, soil overlying a bed of useful mineral.

*Packing* (Corn.), final dressing of tin or copper ore.

*Pacos* (Span.), ferruginous silver ores.

*Panning*, washing earth or crushed rock in a shallow dish (see p. 325).

*Pasilla* (Span.), dry silver amalgam.

*Peach stone* (Corn.), chlorite schist.

*Pee* (Derb.), a fragment of lead ore.

*Pepeñado* (Span.), dressed ore.

*Pitch* (Corn.), portion of lode worked by tributers.

*Pillion* (Corn.), metal remaining in slag.

*Piping*, hydraulicing.

*Placer*, an alluvial mine.

*Plata* (Span.), silver.

*Plata cornea amarillia* (Span.), iodyrite.

*Plata cornea blanca* (Span.), cerargyrite.

*Plata cornea verde* (Span.), embolite.

*Plata mixta* (Span.), gold and silver alloy.

*Plata negra* (Span.), argentite.

*Plata pasta* (Span.), spongy silver bars after retorting.

*Plata piña* (Span.), silver after retorting.

*Plata verde* (Span.), bromyrite.

*Plate* (N. Eng.), scaly shale in limestone beds.

*Plomb d'œuvre* (Fr.), dressed galena.

*Plomo* (Span.), lead, galena.

*Plush copper*, chalcotrichite.

*Plwm* (Wales), lead.

*Poch-erz* (Germ.), ore requiring to be crushed and dressed.

*Podar* (Corn.), copper pyrites.

*Polroz* (Corn.), water-wheel pit.

*Poleillos* (Span.), rich ores.

*Polvounla* (Span.), black silver.

*Pot grownan* (Corn.), decomposed granite.

*Prian* (Corn.), soft white clay.

*Prill* (Corn.), the best ore after cobbing.

*Pryan* (Corn.), see *Prian*.

*Pulp*, crushed ore, wet or dry.

*Quijado* (Span.), dull lead ore.

*Quetschwerk* (Germ.), ore requiring to be crushed and dressed.

*Quick*, (1) productive; (2) mercury.

*Quillato* (Span.),carat.

*Rabban* (Corn.), yellow dry gossan.

*Rack* (Corn.), a stationary buddle.

*Raffain* (Corn.), poor ore.

- Rag burning* (Corn.), the first roasting of tin-witts.  
*Ragging* (Corn.), rough cobbing.  
*Rake* (Corn.), a vein : (Derb.), fissure vein crossing strata.  
*Ramble* (N. Eng.), shale bed overlying coal.  
*Red rab* (Corn.) red slaty rock.  
*Reliz* (Span.), wall of lode.  
*Rich* (N. Amer.), open heap in which coal is coked.  
*Rifle*, a groove or check on the floor of a sluice to catch gold.  
*Rimrock*, bed rock forming a boundary to gravel deposit.  
*Rosiclara* (Span.), ruby silver ore.  
*Roughs* (Corn.), second quality tin sands.  
  
*Scovan* (Corn.), a tin lode showing no gossan at surface.  
*Scove* (Corn.), purest tin ore.  
*Scrin* (Derb.), a small vein.  
*Scrowl* (Corn.), loose ore where a vein is crossed.  
*Seam* (Corn.), a horse-load of ore.  
*Shadd* (Corn.), rounded fragments of ore overlying a vein.  
*Shot* (Staff.), fallen roof of coal mine.  
*Shout* (Corn.), see Shadd.  
*Shoading* (Corn.), prospecting.  
*Sickening*, see Flouring.  
*Siddle*, inclination.  
*Skinpings* (Corn.), the poorest ore skimmed off the jigger.  
*Skip*, a box for raising ore.  
*Skit* (Corn.), a pump.  
*Slack*, small coal.  
*Sleck* (Derb.), mud in a mine.  
*Sleeping-table* (Corn.), a buddle.  
*Slickensides*, polished surfaces of vein walls.  
*Slimes*, most finely crushed ore.  
*Sludge*, see Slimes.  
*Sluice*, a long channel in rock or of timber, with checks to catch gold.  
*Slurry* (N. Wales), half smelted ore.  
*Smeddum*, lead ore dust.  
*Smut* (Staff.), soft bad coal.  
*Sollar* (Corn.), platform, landing.  
*Spall*, to break ore for dressing.  
*Speiss* (Germ.), impure arsenides produced in copper and lead smelting.  
*Spiegel Eisen* (Germ.), manganiferous white cast iron.  
*Spills* (Corn.), a temporary lagging driven ahead on levels in loose ground.  
*Squat* (Corn.), tin ore mixed with spar.  
*S. andage*, pump reservoir.  
*Stannary*, tin works.  
*Stope*, to excavate mineral in a series of steps.  
*Stowce*, (1) windlass ; (2) landmarks.

*Strake*, an inclined table or trough for separating metal from refuse.

*Studdles*, timber props.

*Still*, platform to carry miners or waste.

*Stup*, powdered coke or coal mixed with clay.

*Sturt*, a tribute bargain profitable to the miner.

*Stythe* (N. Eng.), choke-damp.

*Sweeping-table*, a stationary buddle.

*Swither* (N. Amer.), a crevice branching from a main lead lode.

*Tailings*, the refuse flowing from the tail or lowest end of the apparatus.

*Teem*, to pour or tip.

*Tepetate* (Span.), rubbish.

*Thill* (N. Eng.), floor of coal mine.

*Thurl* (Staff.), to cut through from one working into another.

*Ticketing* (Corn.), purchasing ore by tender on tickets.

*Tierras* (Span.), earth impregnated with mercury ore.

*Tin-witts* (Corn.), product of first dressing of tin ores, containing also wolfram and sulphides.

*Tossing*, shaking powdered ore in water to effect separation of heavy and light particles.

*Trapiche* (Span.), a primitive grinding mill.

*Tralooing* (Corn.), stirring tin slimes in water.

*Tributers*, miners paid by results.

*Turbary*, a peat bog.

*Tut-work*, work paid for by the piece, not by results.

*Tye*, a strake.

*Van*, to dress or concentrate ore by hand or machine.

*Vend* (N. Eng.), total sales of coal from a mine.

*Vestry* (N. Eng.), refuse.

*Vinney*, copper ore with green efflorescence.

*Vugh* (Corn.), a cavity.

*Wale* (N. Eng.), hand-dressing coal.

*Wash dirt*, auriferous gravel.

*Woeldon*, old ironstone workings.

*Whim*, a winding drum.

*Whip*, a winding pulley.

*Whits*, see Tin-witts.

*Wild lead*, zinc blende.

*Winze*, interior shaft connecting levels.

*Wythern* (Wales), lode.

*Yellow ore* (Corn.), chalcopryrite.



## LIST OF USEFUL BOOKS.

- André, G. G., Coal Mining, 72s.  
 Beringer, C. & J. J., Text-book of Assaying, for use of those connected with mines, 10s. 6d.  
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 Randall, P. M., Quartz Operator's Handbook, 10s. 6d.  
 Sawyer, A. R., Accidents in Mines; their causes and means of diminishing their frequency, 21s.  
 Smyth, W. W., Coal and Coal Mining, 4s.  
 Stone, T. W., Simple Hydraulic Formulæ, 6s.  
 Van Wagenen, T. F., Manual of Hydraulic Mining, 5s.



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Departure and Minutes.	Measured Distance, or Hypothesis, 1, 10, 100, 1,000, or 10,000.				Measured Distance, or Hypothesis, 2, 20, 200, 2,000, or 20,000.				Measured Distance, or Hypothesis, 3, 30, 300, 3,000, or 30,000.				Measured Distance, or Hypothesis, 4, 40, 400, 4,000, or 40,000.				Measured Distance, or Hypothesis, 5, 50, 500, 5,000, or 50,000.			
	Distance from Place of Departure.	Latitude of Place of Departure.	Longitude of Place of Departure.	Distance to Place of Arrival.	Distance from Place of Departure.	Latitude of Place of Departure.	Longitude of Place of Departure.	Distance to Place of Arrival.	Distance from Place of Departure.	Latitude of Place of Departure.	Longitude of Place of Departure.	Distance to Place of Arrival.	Distance from Place of Departure.	Latitude of Place of Departure.	Longitude of Place of Departure.	Distance to Place of Arrival.	Distance from Place of Departure.	Latitude of Place of Departure.	Longitude of Place of Departure.	Distance to Place of Arrival.
1	0.99930	0.03489	1.99378	0.06978	2.99817	0.10467	3.99756	0.18956	4.99695	0.17445	60									
2	0.99928	0.03529	1.99352	0.07090	2.99811	0.10644	3.99748	0.18102	4.99685	0.17740	68									
3	0.99924	0.03606	1.99368	0.07212	2.99802	0.10818	3.99738	0.18424	4.99670	0.18080	76									
4	0.99920	0.03684	1.99384	0.07328	2.99796	0.10992	3.99728	0.18656	4.99650	0.18320	84									
5	0.99916	0.03722	1.99360	0.07444	2.99790	0.11166	3.99720	0.18888	4.99630	0.18610	92									
6	0.99912	0.03760	1.99356	0.07560	2.99784	0.11340	3.99712	0.19120	4.99610	0.18900	100									
7	0.99908	0.03839	1.99352	0.07676	2.99778	0.11514	3.99704	0.19352	4.99590	0.19190	108									
8	0.99904	0.03896	1.99348	0.07792	2.99772	0.11688	3.99696	0.19584	4.99570	0.19480	116									
9	0.99900	0.03953	1.99344	0.07910	2.99766	0.11862	3.99690	0.19816	4.99550	0.19770	124									
10	0.99896	0.04013	1.99340	0.08028	2.99757	0.12036	3.99684	0.20048	4.99530	0.20065	132									
11	0.99892	0.04071	1.99336	0.08142	2.99751	0.12210	3.99678	0.20280	4.99510	0.20355	140									
12	0.99888	0.04129	1.99332	0.08258	2.99742	0.12384	3.99672	0.20512	4.99490	0.20645	148									
13	0.99884	0.04187	1.99328	0.08374	2.99736	0.12558	3.99666	0.20744	4.99470	0.20935	156									
14	0.99880	0.04245	1.99324	0.08490	2.99727	0.12732	3.99660	0.20976	4.99450	0.21225	164									
15	0.99876	0.04303	1.99320	0.08606	2.99721	0.12906	3.99654	0.21208	4.99430	0.21515	172									
16	0.99872	0.04361	1.99316	0.08722	2.99712	0.13080	3.99648	0.21444	4.99410	0.21805	180									
17	0.99868	0.04420	1.99312	0.08838	2.99706	0.13254	3.99642	0.21680	4.99390	0.22090	188									
18	0.99864	0.04478	1.99308	0.08954	2.99699	0.13428	3.99636	0.21912	4.99370	0.22380	196									
19	0.99860	0.04536	1.99304	0.09070	2.99693	0.13602	3.99630	0.22144	4.99350	0.22670	204									
20	0.99856	0.04594	1.99300	0.09186	2.99687	0.13776	3.99624	0.22376	4.99330	0.22960	212									
21	0.99852	0.04652	1.99296	0.09302	2.99681	0.13950	3.99618	0.22608	4.99310	0.23250	220									
22	0.99848	0.04710	1.99292	0.09418	2.99674	0.14124	3.99612	0.22840	4.99290	0.23540	228									
23	0.99844	0.04768	1.99288	0.09534	2.99668	0.14298	3.99606	0.23072	4.99270	0.23830	236									
24	0.99840	0.04826	1.99284	0.09650	2.99662	0.14472	3.99600	0.23304	4.99250	0.24120	244									
25	0.99836	0.04884	1.99280	0.09766	2.99656	0.14646	3.99594	0.23536	4.99230	0.24410	252									
26	0.99832	0.04942	1.99276	0.09882	2.99650	0.14820	3.99588	0.23768	4.99210	0.24700	260									
27	0.99828	0.05000	1.99272	0.10000	2.99644	0.15000	3.99582	0.24000	4.99190	0.25000	268									
28	0.99824	0.05058	1.99268	0.10116	2.99638	0.15176	3.99576	0.24232	4.99170	0.25290	276									
29	0.99820	0.05116	1.99264	0.10232	2.99632	0.15352	3.99570	0.24464	4.99150	0.25580	284									
30	0.99816	0.05174	1.99260	0.10350	2.99626	0.15528	3.99564	0.24696	4.99130	0.25870	292									
31	0.99812	0.05232	1.99256	0.10466	2.99620	0.15704	3.99558	0.24928	4.99110	0.26160	300									
32	0.99808	0.05290	1.99252	0.10582	2.99614	0.15880	3.99552	0.25160	4.99090	0.26450	308									
33	0.99804	0.05348	1.99248	0.10698	2.99608	0.16056	3.99546	0.25392	4.99070	0.26740	316									
34	0.99800	0.05406	1.99244	0.10814	2.99602	0.16232	3.99540	0.25624	4.99050	0.27030	324									
35	0.99796	0.05464	1.99240	0.10930	2.99596	0.16408	3.99534	0.25856	4.99030	0.27320	332									
36	0.99792	0.05522	1.99236	0.11046	2.99590	0.16584	3.99528	0.26088	4.99010	0.27610	340									
37	0.99788	0.05580	1.99232	0.11162	2.99584	0.16760	3.99522	0.26320	4.98990	0.27900	348									
38	0.99784	0.05638	1.99228	0.11278	2.99578	0.16936	3.99516	0.26552	4.98970	0.28190	356									
39	0.99780	0.05696	1.99224	0.11394	2.99572	0.17112	3.99510	0.26784	4.98950	0.28480	364									
40	0.99776	0.05754	1.99220	0.11510	2.99566	0.17288	3.99504	0.27016	4.98930	0.28770	372									
41	0.99772	0.05812	1.99216	0.11626	2.99560	0.17464	3.99498	0.27248	4.98910	0.29060	380									
42	0.99768	0.05870	1.99212	0.11742	2.99554	0.17640	3.99492	0.27480	4.98890	0.29350	388									
43	0.99764	0.05928	1.99208	0.11858	2.99548	0.17816	3.99486	0.27712	4.98870	0.29640	396									
44	0.99760	0.05986	1.99204	0.11974	2.99542	0.17992	3.99480	0.27944	4.98850	0.29930	404									
45	0.99756	0.06044	1.99200	0.12090	2.99536	0.18168	3.99474	0.28176	4.98830	0.30220	412									
46	0.99752	0.06102	1.99196	0.12206	2.99530	0.18344	3.99468	0.28408	4.98810	0.30510	420									
47	0.99748	0.06160	1.99192	0.12322	2.99524	0.18520	3.99462	0.28640	4.98790	0.30800	428									
48	0.99744	0.06218	1.99188	0.12438	2.99518	0.18696	3.99456	0.28872	4.98770	0.31090	436									
49	0.99740	0.06276	1.99184	0.12554	2.99512	0.18872	3.99450	0.29104	4.98750	0.31380	444									
50	0.99736	0.06334	1.99180	0.12670	2.99506	0.19048	3.99444	0.29336	4.98730	0.31670	452									
51	0.99732	0.06392	1.99176	0.12786	2.99500	0.19224	3.99438	0.29568	4.98710	0.31960	460									
52	0.99728	0.06450	1.99172	0.12902	2.99494	0.19400	3.99432	0.29800	4.98690	0.32250	468									
53	0.99724	0.06508	1.99168	0.13018	2.99488	0.19576	3.99426	0.30032	4.98670	0.32540	476									
54	0.99720	0.06566	1.99164	0.13134	2.99482	0.19752	3.99420	0.30264	4.98650	0.32830	484									
55	0.99716	0.06624	1.99160	0.13250	2.99476	0.19928	3.99414	0.30496	4.98630	0.33120	492									
56	0.99712	0.06682	1.99156	0.13366	2.99470	0.20104	3.99408	0.30728	4.98610	0.33410	500									
57	0.99708	0.06740	1.99152	0.13482	2.99464	0.20280	3.99402	0.30960	4.98590	0.33700	508									
58	0.99704	0.06798	1.99148	0.13598	2.99458	0.20456	3.99396	0.31192	4.98570	0.34000	516									
59	0.99700	0.06856	1.99144	0.13714	2.99452	0.20632	3.99390	0.31424	4.98550	0.34290	524									
60	0.99696	0.06914	1.99140	0.13830	2.99446	0.20808	3.99384	0.31656	4.98530	0.34580	532									
61	0.99692	0.06972	1.99136	0.13946	2.99440	0.20984	3.99378	0.31888	4.98510	0.34870	540									
62	0.99688	0.07030	1.99132	0.14062	2.99434	0.21160	3.99372	0.32120	4.98490	0.35160	548									
63	0.99684	0.07088	1.99128	0.14178	2.99428	0.21336	3.99366	0.32352	4.98470	0.35450	556									
64	0.99680	0.07146	1.99124	0.14294	2.99422	0.21512	3.99360	0.32584	4.98450	0.35740	564									
65	0.99676	0.07204	1.99120	0.14410	2.99416	0.21688	3.99354	0.32816	4.98430	0.36030	572									
66	0.99672	0.07262	1.99116	0.14526	2.99410	0.21864	3.99348	0.33048	4.98410	0.36320	580									
67	0.99668	0.07320	1.99112	0.14642	2.															

Degrees and Minutes.	Measured Distance, or Hypotenuse, 1, 10, 100, 1,000, 10,000, or 100,000.				Measured Distance, or Hypotenuse, 1, 20, 200, 2,000, 20,000, or 200,000.				Measured Distance, or Hypotenuse, 1, 3, 30, 300, 3,000, 30,000, or 300,000.				Measured Distance, or Hypotenuse, 1, 4, 40, 400, 4,000, 40,000, or 400,000.				Measured Distance, or Hypotenuse, 1, 5, 50, 500, 5,000, 50,000, or 500,000.				Degrees and Minutes.
	Distance from Latitude or East.	Distance from Latitude or West.	Distance from Latitude or East.	Distance from Latitude or West.	Distance from Latitude or East.	Distance from Latitude or West.	Distance from Latitude or East.	Distance from Latitude or West.	Distance from Latitude or East.	Distance from Latitude or West.	Distance from Latitude or East.	Distance from Latitude or West.	Distance from Latitude or East.	Distance from Latitude or West.	Distance from Latitude or East.	Distance from Latitude or West.	Distance from Latitude or East.	Distance from Latitude or West.	Distance from Latitude or East.	Distance from Latitude or West.	
2	0.99362	0.05234	1.99724	0.10468	2.99536	0.15702	3.99448	0.20986	4.99310	0.26170	5.99130	0.31448	6.98905	0.36810	7.98625	0.42178	8.98300	0.47545	9.97925	0.52910	02
4	0.99356	0.05349	1.99712	0.10582	2.99577	0.15873	3.99436	0.21164	4.99296	0.26455	5.99065	0.31732	6.98830	0.37100	7.98545	0.42478	8.98260	0.47845	9.97875	0.53175	04
6	0.99353	0.05470	1.99706	0.10714	2.99589	0.16021	3.99412	0.21456	4.99266	0.26745	5.99030	0.32020	6.98790	0.37388	7.98500	0.42755	8.98210	0.48120	9.97825	0.53400	06
8	0.99350	0.05605	1.99700	0.10850	2.99600	0.16170	3.99394	0.21750	4.99246	0.27035	5.98998	0.32300	6.98750	0.37650	7.98450	0.43020	8.98160	0.48380	9.97800	0.53625	08
10	0.99347	0.05744	1.99694	0.11048	2.99611	0.16320	3.99376	0.22048	4.99228	0.27320	5.98980	0.32570	6.98730	0.37900	7.98430	0.43290	8.98140	0.48590	9.97775	0.53850	10
12	0.99344	0.05882	1.99688	0.11264	2.99622	0.16470	3.99358	0.22346	4.99204	0.27590	5.98960	0.32800	6.98710	0.38130	7.98410	0.43500	8.98120	0.48790	9.97750	0.54075	12
14	0.99340	0.06020	1.99680	0.11500	2.99633	0.16620	3.99340	0.22644	4.99186	0.27860	5.98940	0.33010	6.98690	0.38360	7.98400	0.43710	8.98100	0.48990	9.97725	0.54300	14
16	0.99337	0.06158	1.99674	0.11744	2.99644	0.16770	3.99322	0.22942	4.99172	0.28130	5.98920	0.33220	6.98670	0.38570	7.98390	0.43920	8.98080	0.49190	9.97700	0.54525	16
18	0.99334	0.06296	1.99668	0.11988	2.99655	0.16920	3.99304	0.23240	4.99158	0.28400	5.98900	0.33430	6.98650	0.38780	7.98380	0.44130	8.98060	0.49390	9.97675	0.54750	18
20	0.99330	0.06434	1.99660	0.12224	2.99666	0.17070	3.99286	0.23538	4.99144	0.28670	5.98880	0.33640	6.98630	0.38990	7.98370	0.44340	8.98040	0.49590	9.97650	0.54975	20
22	0.99327	0.06572	1.99654	0.12440	2.99677	0.17220	3.99268	0.23836	4.99130	0.28940	5.98860	0.33850	6.98610	0.39200	7.98360	0.44550	8.98020	0.49790	9.97625	0.55200	22
24	0.99323	0.06710	1.99648	0.12656	2.99688	0.17370	3.99250	0.24134	4.99116	0.29210	5.98840	0.34060	6.98590	0.39410	7.98350	0.44760	8.98000	0.49990	9.97600	0.55425	24
26	0.99320	0.06848	1.99640	0.12872	2.99699	0.17520	3.99232	0.24432	4.99102	0.29480	5.98820	0.34270	6.98570	0.39620	7.98340	0.44970	8.97980	0.50190	9.97575	0.55650	26
28	0.99317	0.06986	1.99634	0.13088	2.99710	0.17670	3.99214	0.24730	4.99088	0.29750	5.98800	0.34480	6.98550	0.39830	7.98330	0.45180	8.97960	0.50390	9.97550	0.55875	28
30	0.99313	0.07124	1.99628	0.13304	2.99721	0.17820	3.99196	0.25028	4.99074	0.29960	5.98780	0.34690	6.98530	0.40040	7.98320	0.45390	8.97940	0.50590	9.97525	0.56100	30
32	0.99309	0.07262	1.99620	0.13520	2.99732	0.17970	3.99178	0.25326	4.99060	0.30210	5.98760	0.34900	6.98510	0.40250	7.98310	0.45600	8.97920	0.50790	9.97500	0.56325	32
34	0.99306	0.07399	1.99614	0.13736	2.99743	0.18120	3.99160	0.25624	4.99046	0.30420	5.98740	0.35110	6.98490	0.40460	7.98300	0.45810	8.97900	0.50990	9.97475	0.56550	34
36	0.99302	0.07537	1.99608	0.13952	2.99754	0.18270	3.99142	0.25922	4.99032	0.30630	5.98720	0.35320	6.98470	0.40670	7.98290	0.46020	8.97880	0.51190	9.97450	0.56775	36
38	0.99299	0.07675	1.99600	0.14168	2.99765	0.18420	3.99124	0.26220	4.99018	0.30840	5.98700	0.35530	6.98450	0.40880	7.98280	0.46230	8.97860	0.51390	9.97425	0.56975	38
40	0.99295	0.07813	1.99594	0.14384	2.99776	0.18570	3.99106	0.26518	4.99004	0.31050	5.98680	0.35740	6.98430	0.41090	7.98270	0.46440	8.97840	0.51590	9.97400	0.57200	40
42	0.99291	0.07951	1.99588	0.14600	2.99787	0.18720	3.99088	0.26816	4.98990	0.31260	5.98660	0.35950	6.98410	0.41300	7.98260	0.46650	8.97820	0.51790	9.97375	0.57425	42
44	0.99287	0.08089	1.99580	0.14816	2.99798	0.18870	3.99070	0.27114	4.98976	0.31470	5.98640	0.36160	6.98390	0.41510	7.98250	0.46860	8.97800	0.51990	9.97350	0.57650	44
46	0.99284	0.08227	1.99574	0.15032	2.99809	0.19020	3.99052	0.27412	4.98962	0.31680	5.98620	0.36370	6.98370	0.41720	7.98240	0.47070	8.97780	0.52190	9.97325	0.57875	46
48	0.99280	0.08365	1.99568	0.15248	2.99820	0.19170	3.99034	0.27710	4.98948	0.31890	5.98600	0.36580	6.98350	0.41930	7.98230	0.47280	8.97760	0.52390	9.97300	0.58100	48
50	0.99277	0.08503	1.99560	0.15464	2.99831	0.19320	3.99016	0.28008	4.98934	0.32100	5.98580	0.36790	6.98330	0.42140	7.98220	0.47490	8.97740	0.52590	9.97275	0.58325	50
52	0.99272	0.08641	1.99554	0.15680	2.99842	0.19470	3.99000	0.28306	4.98920	0.32310	5.98560	0.37000	6.98310	0.42350	7.98210	0.47700	8.97720	0.52790	9.97250	0.58550	52
54	0.99268	0.08779	1.99548	0.15896	2.99853	0.19620	3.98982	0.28604	4.98906	0.32520	5.98540	0.37210	6.98290	0.42560	7.98200	0.47910	8.97700	0.52990	9.97225	0.58775	54
56	0.99264	0.08917	1.99540	0.16112	2.99864	0.19770	3.98964	0.28902	4.98892	0.32730	5.98520	0.37420	6.98270	0.42770	7.98190	0.48120	8.97680	0.53190	9.97200	0.58975	56
58	0.99260	0.09055	1.99534	0.16328	2.99875	0.19920	3.98946	0.29200	4.98878	0.32940	5.98500	0.37630	6.98250	0.42980	7.98180	0.48330	8.97660	0.53390	9.97175	0.59200	58
60	0.99256	0.09193	1.99528	0.16544	2.99886	0.20070	3.98928	0.29498	4.98864	0.33150	5.98480	0.37840	6.98230	0.43190	7.98170	0.48540	8.97640	0.53590	9.97150	0.59425	60

### TRAVERSE TABLES.

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Degrees and Minutes	Measured Distance, or Hypothenuse, of 1, 10, 100, 1000, or 100,000.				Measured Distance, or Hypothenuse, of 1, 20, 300, 2000, or 300,000.				Measured Distance, or Hypothenuse, of 1, 40, 400, 4000, or 400,000.				Measured Distance, or Hypothenuse, of 1, 50, 500, 5000, or 500,000.				Degrees and Minutes
	Distance from North or South	Latitude or East or West	Distance from North or South	Distance from North or South	Distance from North or South	Latitude or East or West	Distance from North or South	Distance from North or South	Distance from North or South	Latitude or East or West	Distance from North or South	Distance from North or South	Distance from North or South	Distance from North or South	Latitude or East or West	Distance from North or South	
1	0.999956	0.669793	1.395152	0.139522	2.892268	0.289223	3.392024	0.339204	3.891780	0.389180	4.391565	0.439155	4.891350	0.489135	5.391120	0.539112	5.890896
2	0.999756	0.670033	1.395104	0.139522	2.892256	0.289209	3.392008	0.339192	3.891732	0.389116	4.391499	0.439145	4.891276	0.489112	5.390984	0.539084	5.890896
3	0.999556	0.670273	1.395056	0.139522	2.892244	0.289161	3.391960	0.339144	3.891684	0.389080	4.391451	0.439116	4.891228	0.489064	5.390744	0.539044	5.890896
4	0.999356	0.670513	1.395008	0.139522	2.892232	0.289113	3.391912	0.339128	3.891636	0.389032	4.391403	0.439080	4.891200	0.489016	5.390504	0.539004	5.890896
5	0.999156	0.670753	1.394960	0.139522	2.892220	0.289065	3.391864	0.339112	3.891590	0.388984	4.391359	0.439064	4.891176	0.488968	5.390304	0.539004	5.890896
6	0.998956	0.670993	1.394912	0.139522	2.892208	0.289017	3.391812	0.339096	3.891544	0.388936	4.391315	0.439032	4.891152	0.488920	5.390104	0.539004	5.890896
7	0.998756	0.671233	1.394864	0.139522	2.892196	0.288969	3.391764	0.339080	3.891496	0.388888	4.391277	0.439016	4.891128	0.488872	5.389904	0.539004	5.890896
8	0.998556	0.671473	1.394816	0.139522	2.892184	0.288921	3.391712	0.339064	3.891450	0.388840	4.391239	0.438992	4.891104	0.488824	5.389704	0.539004	5.890896
9	0.998356	0.671713	1.394768	0.139522	2.892172	0.288873	3.391664	0.339048	3.891404	0.388792	4.391201	0.438968	4.891088	0.488776	5.389504	0.539004	5.890896
10	0.998156	0.671953	1.394720	0.139522	2.892160	0.288825	3.391616	0.339032	3.891358	0.388744	4.391163	0.438944	4.891040	0.488728	5.389304	0.539004	5.890896
11	0.997956	0.672193	1.394672	0.139522	2.892148	0.288777	3.391568	0.339016	3.891312	0.388696	4.391125	0.438920	4.890992	0.488704	5.389104	0.539004	5.890896
12	0.997756	0.672433	1.394624	0.139522	2.892136	0.288729	3.391520	0.338996	3.891264	0.388656	4.391087	0.438896	4.890944	0.488680	5.388904	0.539004	5.890896
13	0.997556	0.672673	1.394576	0.139522	2.892124	0.288681	3.391472	0.338976	3.891216	0.388608	4.391049	0.438872	4.890896	0.488640	5.388704	0.539004	5.890896
14	0.997356	0.672913	1.394528	0.139522	2.892112	0.288633	3.391424	0.338956	3.891168	0.388560	4.391011	0.438848	4.890848	0.488608	5.388504	0.539004	5.890896
15	0.997156	0.673153	1.394480	0.139522	2.892100	0.288585	3.391376	0.338936	3.891120	0.388512	4.390973	0.438824	4.890800	0.488568	5.388304	0.539004	5.890896
16	0.996956	0.673393	1.394432	0.139522	2.892088	0.288537	3.391328	0.338916	3.891072	0.388464	4.390935	0.438800	4.890752	0.488520	5.388104	0.539004	5.890896
17	0.996756	0.673633	1.394384	0.139522	2.892076	0.288489	3.391280	0.338896	3.891024	0.388416	4.390897	0.438784	4.890688	0.488472	5.387904	0.539004	5.890896
18	0.996556	0.673873	1.394336	0.139522	2.892064	0.288441	3.391232	0.338876	3.890976	0.388368	4.390859	0.438760	4.890640	0.488424	5.387704	0.539004	5.890896
19	0.996356	0.674113	1.394288	0.139522	2.892052	0.288393	3.391184	0.338856	3.890928	0.388320	4.390821	0.438736	4.890592	0.488376	5.387504	0.539004	5.890896
20	0.996156	0.674353	1.394240	0.139522	2.892040	0.288345	3.391136	0.338836	3.890880	0.388272	4.390783	0.438712	4.890544	0.488328	5.387304	0.539004	5.890896
21	0.995956	0.674593	1.394192	0.139522	2.892028	0.288297	3.391088	0.338816	3.890832	0.388224	4.390745	0.438688	4.890506	0.488280	5.387104	0.539004	5.890896
22	0.995756	0.674833	1.394144	0.139522	2.892016	0.288249	3.391040	0.338796	3.890784	0.388176	4.390707	0.438664	4.890468	0.488232	5.386904	0.539004	5.890896
23	0.995556	0.675073	1.394096	0.139522	2.892004	0.288201	3.390992	0.338776	3.890736	0.388128	4.390669	0.438640	4.890424	0.488184	5.386704	0.539004	5.890896
24	0.995356	0.675313	1.394048	0.139522	2.891992	0.288153	3.390944	0.338756	3.890688	0.388080	4.390631	0.438616	4.890386	0.488136	5.386504	0.539004	5.890896
25	0.995156	0.675553	1.394000	0.139522	2.891980	0.288105	3.390896	0.338736	3.890640	0.388032	4.390593	0.438592	4.890348	0.488088	5.386304	0.539004	5.890896
26	0.994956	0.675793	1.393952	0.139522	2.891968	0.288057	3.390848	0.338716	3.890592	0.387984	4.390555	0.438568	4.890304	0.488040	5.386104	0.539004	5.890896
27	0.994756	0.676033	1.393904	0.139522	2.891956	0.288009	3.390800	0.338696	3.890544	0.387936	4.390517	0.438544	4.890266	0.488000	5.385904	0.539004	5.890896
28	0.994556	0.676273	1.393856	0.139522	2.891944	0.287961	3.390752	0.338676	3.890496	0.387888	4.390479	0.438520	4.890224	0.487952	5.385704	0.539004	5.890896
29	0.994356	0.676513	1.393808	0.139522	2.891932	0.287913	3.390704	0.338656	3.890448	0.387840	4.390441	0.438496	4.890186	0.487904	5.385504	0.539004	5.890896
30	0.994156	0.676753	1.393760	0.139522	2.891920	0.287865	3.390656	0.338636	3.890400	0.387792	4.390403	0.438472	4.890144	0.487856	5.385304	0.539004	5.890896
31	0.993956	0.676993	1.393712	0.139522	2.891908	0.287817	3.390608	0.338616	3.890352	0.387744	4.390365	0.438448	4.890096	0.487808	5.385104	0.539004	5.890896
32	0.993756	0.677233	1.393664	0.139522	2.891896	0.287769	3.390560	0.338596	3.890304	0.387696	4.390327	0.438424	4.890048	0.487760	5.384904	0.539004	5.890896
33	0.993556	0.677473	1.393616	0.139522	2.891884	0.287721	3.390512	0.338576	3.890256	0.387648	4.390289	0.438400	4.889992	0.487712	5.384704	0.539004	5.890896
34	0.993356	0.677713	1.393568	0.139522	2.891872	0.287673	3.390464	0.338556	3.890208	0.387600	4.390251	0.438376	4.889944	0.487664	5.384504	0.539004	5.890896
35	0.993156	0.677953	1.393520	0.139522	2.891860	0.287625	3.390416	0.338536	3.890160	0.387552	4.390213	0.438352	4.889896	0.487616	5.384304	0.539004	5.890896
36	0.992956	0.678193	1.393472	0.139522	2.891848	0.287577	3.390368	0.338516	3.890112	0.387504	4.390175	0.438328	4.889848	0.487568	5.384104	0.539004	5.890896
37	0.992756	0.678433	1.393424	0.139522	2.891836	0.287529	3.390320	0.338496	3.890064	0.387456	4.390137	0.438304	4.889800	0.487520	5.383904	0.539004	5.890896
38	0.992556	0.678673	1.393376	0.139522	2.891824	0.287481	3.390272	0.338476	3.890016	0.387408	4.390099	0.438280	4.889752	0.487472	5.383704	0.539004	5.890896
39	0.992356	0.678913	1.393328	0.139522	2.891812	0.287433	3.390224	0.338456	3.889968	0.387360	4.390061	0.438256	4.889704	0.487424	5.383504	0.539004	5.890896
40	0.992156	0.679153	1.393280	0.139522	2.891800	0.287385	3.390176	0.338436	3.889920	0.387312	4.390023	0.438232	4.889656	0.487376	5.383304	0.539004	5.890896
41	0.991956	0.679393	1.393232	0.139522	2.891788	0.287337	3.390128	0.338416	3.889872	0.387264	4.389985	0.438208	4.889608	0.487328	5.383104	0.539004	5.890896
42	0.991756	0.679633	1.393184	0.139522	2.891776	0.287289	3.390080	0.338396	3.889824	0.387216	4.389947	0.438184	4.889560	0.487280	5.382904	0.539004	5.890896
43	0.991556	0.679873	1.393136	0.139522	2.891764	0.287241	3.390032	0.338376	3.889776	0.387168	4.389909	0.438160	4.889512	0.487232	5.382704	0.539004	5.890896
44	0.991356	0.680113	1.393088	0.139522	2.891752	0.287193	3.390000	0.338356	3.889728	0.387120	4.389871	0.438136	4.889464	0.487184	5.382504	0.539004	5.890896
45	0.991156	0.680353	1.393040	0.139522	2.891740	0.287145	3.389952	0.338336	3.889680	0.387072	4.389833	0.438112	4.889416	0.487136	5.382304	0.539004	5.890896
46	0.990956	0.680593	1.393000	0.139522	2.891728	0.287097	3.389904	0.338316	3.889632	0.387024	4.389795	0.438088	4.889368	0.487088	5.382104	0.539004	5.890896
47	0.990756	0.680833	1.392952	0.139522	2.891716	0.287049	3.389856	0.338296	3.889584	0.386976	4.389757	0.438064	4.889320	0.487040	5.381904	0.539004	5.890896
48	0.990556	0.681073	1.392904	0.139522	2.891704	0.287001	3.389808	0.338276	3.889536	0.386928	4.389719	0.438040	4.889272	0.486992	5.381704	0.539004	5.890896
49	0.990356	0.681313	1.392856	0.139522	2.891692	0.286953	3.389760	0.338256	3.889488	0.386880	4.389681	0.438016	4.889224	0.486944	5.381504	0.539004	5.890896
50	0.990156	0.681553	1.392808	0.139522	2.891680	0.286905	3.389712	0.338236	3.889440	0.386832	4.389643	0.437992	4.889176	0.486896	5.381304	0.539004	5.890896
51	0.989956	0.681793	1.392760	0.139522	2.891668	0.286857	3.389664	0.338216	3.889392	0.386784	4.389605	0.437968	4.889128	0.486848	5.381104	0.539004	5.890896
52	0.989756	0.682033	1.392712	0.139522	2.891656	0.286809	3.389616	0.338196	3.889344	0.386736	4.389567	0.437944	4.889080				

Degrees and Minutes	Measured Distance, or Hypothenuse, 1, 10, 100, 1000, or 100,000.			Measured Distance, or Hypothenuse, 2, 20, 200, 2000, or 200,000.			Measured Distance, or Hypothenuse, 3, 30, 300, 3000, or 300,000.			Measured Distance, or Hypothenuse, 4, 40, 400, 4000, or 400,000.			Measured Distance, or Hypothenuse, 5, 50, 500, 5000, or 500,000.			Measured Distance, or Hypothenuse, 6, 60, 600, 6000, or 600,000.		
	Distance from East or West	Distance from North or South	Distance from East or West	Distance from North or South	Distance from East or West	Distance from North or South	Distance from East or West	Distance from North or South	Distance from East or West	Distance from North or South	Distance from East or West	Distance from North or South	Distance from East or West	Distance from North or South	Distance from East or West	Distance from North or South		
5	0.990104	0.087155	1.092383	0.174310	2.948529	0.261425	3.984572	0.358175	4.989070	0.438775	59							
6	0.990112	0.087305	1.092426	0.174740	2.948829	0.261855	3.984872	0.358505	4.989370	0.439105	60							
7	0.990120	0.087455	1.092469	0.175170	2.949129	0.262285	3.985172	0.358835	4.989670	0.439435	55							
8	0.990128	0.087605	1.092512	0.175600	2.949429	0.262715	3.985472	0.359165	4.989970	0.439765	56							
9	0.990136	0.087755	1.092555	0.176030	2.949729	0.263145	3.985772	0.359495	4.990270	0.440095	57							
10	0.990144	0.087905	1.092598	0.176460	2.950029	0.263575	3.986072	0.359825	4.990570	0.440425	52							
11	0.990152	0.088055	1.092641	0.176890	2.950329	0.264005	3.986372	0.360155	4.990870	0.440755	50							
12	0.990160	0.088205	1.092684	0.177320	2.950629	0.264435	3.986672	0.360485	4.991170	0.441085	48							
13	0.990168	0.088355	1.092727	0.177750	2.950929	0.264865	3.986972	0.360815	4.991470	0.441415	46							
14	0.990176	0.088505	1.092770	0.178180	2.951229	0.265295	3.987272	0.361145	4.991770	0.441745	44							
15	0.990184	0.088655	1.092813	0.178610	2.951529	0.265725	3.987572	0.361475	4.992070	0.442075	42							
16	0.990192	0.088805	1.092856	0.179040	2.951829	0.266155	3.987872	0.361805	4.992370	0.442405	40							
17	0.990200	0.088955	1.092899	0.179470	2.952129	0.266585	3.988172	0.362135	4.992670	0.442735	38							
18	0.990208	0.089105	1.092942	0.179900	2.952429	0.267015	3.988472	0.362465	4.992970	0.443065	36							
19	0.990216	0.089255	1.092985	0.180330	2.952729	0.267445	3.988772	0.362795	4.993270	0.443395	34							
20	0.990224	0.089405	1.093028	0.180760	2.953029	0.267875	3.989072	0.363125	4.993570	0.443725	32							
21	0.990232	0.089555	1.093071	0.181190	2.953329	0.268305	3.989372	0.363455	4.993870	0.444055	30							
22	0.990240	0.089705	1.093114	0.181620	2.953629	0.268735	3.989672	0.363785	4.994170	0.444385	28							
23	0.990248	0.089855	1.093157	0.182050	2.953929	0.269165	3.989972	0.364115	4.994470	0.444715	26							
24	0.990256	0.089999	1.093200	0.182480	2.954229	0.269595	3.990272	0.364445	4.994770	0.445045	24							
25	0.990264	0.090149	1.093243	0.182910	2.954529	0.270025	3.990572	0.364775	4.995070	0.445375	22							
26	0.990272	0.090299	1.093286	0.183340	2.954829	0.270455	3.990872	0.365105	4.995370	0.445705	20							
27	0.990280	0.090449	1.093329	0.183770	2.955129	0.270885	3.991172	0.365435	4.995670	0.446035	18							
28	0.990288	0.090599	1.093372	0.184200	2.955429	0.271315	3.991472	0.365765	4.995970	0.446365	16							
29	0.990296	0.090749	1.093415	0.184630	2.955729	0.271745	3.991772	0.366095	4.996270	0.446695	14							
30	0.990304	0.090899	1.093458	0.185060	2.956029	0.272175	3.992072	0.366425	4.996570	0.447025	12							
31	0.990312	0.091049	1.093501	0.185490	2.956329	0.272605	3.992372	0.366755	4.996870	0.447355	10							
32	0.990320	0.091199	1.093544	0.185920	2.956629	0.273035	3.992672	0.367085	4.997170	0.447685	8							
33	0.990328	0.091349	1.093587	0.186350	2.956929	0.273465	3.992972	0.367415	4.997470	0.448015	6							
34	0.990336	0.091499	1.093630	0.186780	2.957229	0.273895	3.993272	0.367745	4.997770	0.448345	4							
35	0.990344	0.091649	1.093673	0.187210	2.957529	0.274325	3.993572	0.368075	4.998070	0.448675	2							
36	0.990352	0.091799	1.093716	0.187640	2.957829	0.274755	3.993872	0.368405	4.998370	0.449005	84							
37	0.990360	0.091949	1.093759	0.188070	2.958129	0.275185	3.994172	0.368735	4.998670	0.449335								
38	0.990368	0.092099	1.093802	0.188500	2.958429	0.275615	3.994472	0.369065	4.998970	0.449665								
39	0.990376	0.092249	1.093845	0.188930	2.958729	0.276045	3.994772	0.369395	4.999270	0.449995								
40	0.990384	0.092399	1.093888	0.189360	2.959029	0.276475	3.995072	0.369725	4.999570	0.450325								
41	0.990392	0.092549	1.093931	0.189790	2.959329	0.276905	3.995372	0.370055	4.999870	0.450655								
42	0.990400	0.092699	1.093974	0.190220	2.959629	0.277335	3.995672	0.370385	5.000170	0.450985								
43	0.990408	0.092849	1.094017	0.190650	2.959929	0.277765	3.995972	0.370715	5.000470	0.451315								
44	0.990416	0.092999	1.094060	0.191080	2.960229	0.278195	3.996272	0.371045	5.000770	0.451645								
45	0.990424	0.093149	1.094103	0.191510	2.960529	0.278625	3.996572	0.371375	5.001070	0.451975								
46	0.990432	0.093299	1.094146	0.191940	2.960829	0.279055	3.996872	0.371705	5.001370	0.452305								
47	0.990440	0.093449	1.094189	0.192370	2.961129	0.279485	3.997172	0.372035	5.001670	0.452635								
48	0.990448	0.093599	1.094232	0.192800	2.961429	0.279915	3.997472	0.372365	5.001970	0.452965								
49	0.990456	0.093749	1.094275	0.193230	2.961729	0.280345	3.997772	0.372695	5.002270	0.453295								
50	0.990464	0.093899	1.094318	0.193660	2.962029	0.280775	3.998072	0.373025	5.002570	0.453625								
51	0.990472	0.094049	1.094361	0.194090	2.962329	0.281205	3.998372	0.373355	5.002870	0.453955								
52	0.990480	0.094199	1.094404	0.194520	2.962629	0.281635	3.998672	0.373685	5.003170	0.454285								
53	0.990488	0.094349	1.094447	0.194950	2.962929	0.282065	3.998972	0.374015	5.003470	0.454615								
54	0.990496	0.094499	1.094490	0.195380	2.963229	0.282495	3.999272	0.374345	5.003770	0.454945								
55	0.990504	0.094649	1.094533	0.195810	2.963529	0.282925	3.999572	0.374675	5.004070	0.455275								
56	0.990512	0.094799	1.094576	0.196240	2.963829	0.283355	3.999872	0.375005	5.004370	0.455605								
57	0.990520	0.094949	1.094619	0.196670	2.964129	0.283785	4.000172	0.375335	5.004670	0.455935								
58	0.990528	0.095099	1.094662	0.197100	2.964429	0.284215	4.000472	0.375665	5.004970	0.456265								
59	0.990536	0.095249	1.094705	0.197530	2.964729	0.284645	4.000772	0.375995	5.005270	0.456595								
60	0.990544	0.095399	1.094748	0.197960	2.965029	0.285075	4.001072	0.376325	5.005570	0.456925								

Degrees and Minutes	Measured Distance, or Hypothenuse, 1, 10, 100, 1000, 10,000, or 100,000.				Measured Distance, or Hypothenuse, 2, 20, 200, 2000, 20,000, or 200,000.				Measured Distance, or Hypothenuse, 3, 30, 300, 3000, 30,000, or 300,000.				Measured Distance, or Hypothenuse, 4, 40, 400, 4000, 40,000, or 400,000.				Measured Distance, or Hypothenuse, 5, 50, 500, 5000, 50,000, or 500,000.				Degrees and Minutes
	Distance from North or East	Latitude of Place	Distance from North or East	Latitude of Place	Distance from North or East	Latitude of Place	Distance from North or East	Latitude of Place	Distance from North or East	Latitude of Place	Distance from North or East	Latitude of Place	Distance from North or East	Latitude of Place	Distance from North or East	Latitude of Place	Distance from North or East	Latitude of Place			
0	0.994521	0.104523	1.998020	0.209056	2.998353	0.313521	3.997804	0.418112	4.997260	5.996840	6.996535	7.996335	8.996140	9.995945	10.995750	11.995555	12.995360	13.995165	14.994970	0	
1	0.994469	0.105017	1.998020	0.210056	2.998353	0.313521	3.997804	0.418112	4.997260	5.996840	6.996535	7.996335	8.996140	9.995945	10.995750	11.995555	12.995360	13.995165	14.994970	1	
2	0.994389	0.105515	1.998020	0.211056	2.998353	0.313521	3.997804	0.418112	4.997260	5.996840	6.996535	7.996335	8.996140	9.995945	10.995750	11.995555	12.995360	13.995165	14.994970	2	
3	0.994337	0.106024	1.998020	0.212056	2.998353	0.313521	3.997804	0.418112	4.997260	5.996840	6.996535	7.996335	8.996140	9.995945	10.995750	11.995555	12.995360	13.995165	14.994970	3	
4	0.994278	0.106542	1.998020	0.213056	2.998353	0.313521	3.997804	0.418112	4.997260	5.996840	6.996535	7.996335	8.996140	9.995945	10.995750	11.995555	12.995360	13.995165	14.994970	4	
5	0.994213	0.107071	1.998020	0.214056	2.998353	0.313521	3.997804	0.418112	4.997260	5.996840	6.996535	7.996335	8.996140	9.995945	10.995750	11.995555	12.995360	13.995165	14.994970	5	
6	0.994151	0.107611	1.998020	0.215056	2.998353	0.313521	3.997804	0.418112	4.997260	5.996840	6.996535	7.996335	8.996140	9.995945	10.995750	11.995555	12.995360	13.995165	14.994970	6	
7	0.994088	0.108166	1.998020	0.216056	2.998353	0.313521	3.997804	0.418112	4.997260	5.996840	6.996535	7.996335	8.996140	9.995945	10.995750	11.995555	12.995360	13.995165	14.994970	7	
8	0.994024	0.108734	1.998020	0.217056	2.998353	0.313521	3.997804	0.418112	4.997260	5.996840	6.996535	7.996335	8.996140	9.995945	10.995750	11.995555	12.995360	13.995165	14.994970	8	
9	0.993961	0.109314	1.998020	0.218056	2.998353	0.313521	3.997804	0.418112	4.997260	5.996840	6.996535	7.996335	8.996140	9.995945	10.995750	11.995555	12.995360	13.995165	14.994970	9	
10	0.993896	0.110012	1.998020	0.219056	2.998353	0.313521	3.997804	0.418112	4.997260	5.996840	6.996535	7.996335	8.996140	9.995945	10.995750	11.995555	12.995360	13.995165	14.994970	10	
11	0.993833	0.110729	1.998020	0.220056	2.998353	0.313521	3.997804	0.418112	4.997260	5.996840	6.996535	7.996335	8.996140	9.995945	10.995750	11.995555	12.995360	13.995165	14.994970	11	
12	0.993771	0.111465	1.998020	0.221056	2.998353	0.313521	3.997804	0.418112	4.997260	5.996840	6.996535	7.996335	8.996140	9.995945	10.995750	11.995555	12.995360	13.995165	14.994970	12	
13	0.993702	0.112217	1.998020	0.222056	2.998353	0.313521	3.997804	0.418112	4.997260	5.996840	6.996535	7.996335	8.996140	9.995945	10.995750	11.995555	12.995360	13.995165	14.994970	13	
14	0.993637	0.112985	1.998020	0.223056	2.998353	0.313521	3.997804	0.418112	4.997260	5.996840	6.996535	7.996335	8.996140	9.995945	10.995750	11.995555	12.995360	13.995165	14.994970	14	
15	0.993571	0.113769	1.998020	0.224056	2.998353	0.313521	3.997804	0.418112	4.997260	5.996840	6.996535	7.996335	8.996140	9.995945	10.995750	11.995555	12.995360	13.995165	14.994970	15	
16	0.993505	0.114569	1.998020	0.225056	2.998353	0.313521	3.997804	0.418112	4.997260	5.996840	6.996535	7.996335	8.996140	9.995945	10.995750	11.995555	12.995360	13.995165	14.994970	16	
17	0.993439	0.115385	1.998020	0.226056	2.998353	0.313521	3.997804	0.418112	4.997260	5.996840	6.996535	7.996335	8.996140	9.995945	10.995750	11.995555	12.995360	13.995165	14.994970	17	
18	0.993372	0.116217	1.998020	0.227056	2.998353	0.313521	3.997804	0.418112	4.997260	5.996840	6.996535	7.996335	8.996140	9.995945	10.995750	11.995555	12.995360	13.995165	14.994970	18	
19	0.993305	0.117065	1.998020	0.228056	2.998353	0.313521	3.997804	0.418112	4.997260	5.996840	6.996535	7.996335	8.996140	9.995945	10.995750	11.995555	12.995360	13.995165	14.994970	19	
20	0.993238	0.117929	1.998020	0.229056	2.998353	0.313521	3.997804	0.418112	4.997260	5.996840	6.996535	7.996335	8.996140	9.995945	10.995750	11.995555	12.995360	13.995165	14.994970	20	
21	0.993170	0.118809	1.998020	0.230056	2.998353	0.313521	3.997804	0.418112	4.997260	5.996840	6.996535	7.996335	8.996140	9.995945	10.995750	11.995555	12.995360	13.995165	14.994970	21	
22	0.993102	0.119704	1.998020	0.231056	2.998353	0.313521	3.997804	0.418112	4.997260	5.996840	6.996535	7.996335	8.996140	9.995945	10.995750	11.995555	12.995360	13.995165	14.994970	22	
23	0.993034	0.120614	1.998020	0.232056	2.998353	0.313521	3.997804	0.418112	4.997260	5.996840	6.996535	7.996335	8.996140	9.995945	10.995750	11.995555	12.995360	13.995165	14.994970	23	
24	0.992966	0.121539	1.998020	0.233056	2.998353	0.313521	3.997804	0.418112	4.997260	5.996840	6.996535	7.996335	8.996140	9.995945	10.995750	11.995555	12.995360	13.995165	14.994970	24	
25	0.992897	0.122479	1.998020	0.234056	2.998353	0.313521	3.997804	0.418112	4.997260	5.996840	6.996535	7.996335	8.996140	9.995945	10.995750	11.995555	12.995360	13.995165	14.994970	25	
26	0.992828	0.123434	1.998020	0.235056	2.998353	0.313521	3.997804	0.418112	4.997260	5.996840	6.996535	7.996335	8.996140	9.995945	10.995750	11.995555	12.995360	13.995165	14.994970	26	
27	0.992758	0.124404	1.998020	0.236056	2.998353	0.313521	3.997804	0.418112	4.997260	5.996840	6.996535	7.996335	8.996140	9.995945	10.995750	11.995555	12.995360	13.995165	14.994970	27	
28	0.992688	0.125389	1.998020	0.237056	2.998353	0.313521	3.997804	0.418112	4.997260	5.996840	6.996535	7.996335	8.996140	9.995945	10.995750	11.995555	12.995360	13.995165	14.994970	28	
29	0.992617	0.126389	1.998020	0.238056	2.998353	0.313521	3.997804	0.418112	4.997260	5.996840	6.996535	7.996335	8.996140	9.995945	10.995750	11.995555	12.995360	13.995165	14.994970	29	
30	0.992546	0.127404	1.998020	0.239056	2.998353	0.313521	3.997804	0.418112	4.997260	5.996840	6.996535	7.996335	8.996140	9.995945	10.995750	11.995555	12.995360	13.995165	14.994970	30	
31	0.992474	0.128434	1.998020	0.240056	2.998353	0.313521	3.997804	0.418112	4.997260	5.996840	6.996535	7.996335	8.996140	9.995945	10.995750	11.995555	12.995360	13.995165	14.994970	31	
32	0.992402	0.129479	1.998020	0.241056	2.998353	0.313521	3.997804	0.418112	4.997260	5.996840	6.996535	7.996335	8.996140	9.995945	10.995750	11.995555	12.995360	13.995165	14.994970	32	
33	0.992329	0.130539	1.998020	0.242056	2.998353	0.313521	3.997804	0.418112	4.997260	5.996840	6.996535	7.996335	8.996140	9.995945	10.995750	11.995555	12.995360	13.995165	14.994970	33	
34	0.992256	0.131614	1.998020	0.243056	2.998353	0.313521	3.997804	0.418112	4.997260	5.996840	6.996535	7.996335	8.996140	9.995945	10.995750	11.995555	12.995360	13.995165	14.994970	34	
35	0.992182	0.132704	1.998020	0.244056	2.998353	0.313521	3.997804	0.418112	4.997260	5.996840	6.996535	7.996335	8.996140	9.995945	10.995750	11.995555	12.995360	13.995165	14.994970	35	
36	0.992108	0.133809	1.998020	0.245056	2.998353	0.313521	3.997804	0.418112	4.997260	5.996840	6.996535	7.996335	8.996140	9.995945	10.995750	11.995555	12.995360	13.995165	14.994970	36	
37	0.992033	0.134929	1.998020	0.246056	2.998353	0.313521	3.997804	0.418112	4.997260	5.996840	6.996535	7.996335	8.996140	9.995945	10.995750	11.995555	12.995360	13.995165	14.994970	37	
38	0.991958	0.136064	1.998020	0.247056	2.998353	0.313521	3.997804	0.418112	4.997260	5.996840	6.996535	7.996335	8.996140	9.995945	10.995750	11.995555	12.995360	13.995165	14.994970	38	
39	0.991882	0.137214	1.998020	0.248056	2.998353	0.313521	3.997804	0.418112	4.997260	5.996840	6.996535	7.996335	8.996140	9.995945	10.995750	11.995555	12.995360	13.995165	14.994970	39	
40	0.991806	0.138379	1.998020	0.249056	2.998353	0.313521	3.997804	0.418112	4.997260	5.996840	6.996535	7.996335	8.996140	9.995945	10.995750						



Degrees and Minutes.	Measured Distance, or Hypothenuse, 1, 10, 100, 1000, or 100,000.				Measured Distance, or Hypothenuse, 1, 2, 20, 200, 2000, or 200,000.				Measured Distance, or Hypothenuse, 1, 3, 30, 300, 3000, or 300,000.				Measured Distance, or Hypothenuse, 1, 4, 40, 400, 4000, or 400,000.				Measured Distance, or Hypothenuse, 1, 5, 50, 500, 5000, or 500,000.				Degrees and Minutes.
	Distance from Place of Meridian, or North or South.	Latitude of Place of Meridian, or North or South.	Distance from Place of Meridian, or North or South.	Distance from Place of Meridian, or North or South.	Distance from Place of Meridian, or North or South.	Latitude of Place of Meridian, or North or South.	Distance from Place of Meridian, or North or South.	Distance from Place of Meridian, or North or South.	Distance from Place of Meridian, or North or South.	Latitude of Place of Meridian, or North or South.	Distance from Place of Meridian, or North or South.	Distance from Place of Meridian, or North or South.	Distance from Place of Meridian, or North or South.	Latitude of Place of Meridian, or North or South.	Distance from Place of Meridian, or North or South.	Distance from Place of Meridian, or North or South.					
2	0.002045	0.121695	1.935002	0.241378	0.077633	0.345867	3.970184	4.37475	4.892730	0.609315	60										
4	0.002475	0.122545	1.934360	0.244392	0.277126	0.367398	3.969800	4.489784	4.982375	0.612230	58										
6	0.002845	0.123405	1.933680	0.246848	0.297239	0.389072	3.969512	4.602015	5.087015	0.615120	56										
8	0.003215	0.124265	1.932980	0.249304	0.317252	0.410803	3.969224	4.714744	5.196555	0.618005	54										
10	0.003585	0.125125	1.932280	0.251760	0.337265	0.432534	3.968936	4.827372	5.306095	0.620890	52										
12	0.003955	0.125985	1.931580	0.254216	0.357278	0.454266	3.968648	4.940000	5.415635	0.623775	50										
14	0.004325	0.126845	1.930880	0.256672	0.377291	0.475998	3.968360	5.052614	5.525175	0.626660	48										
16	0.004695	0.127705	1.930180	0.259128	0.397304	0.497730	3.968072	5.165182	5.634715	0.629545	46										
18	0.005065	0.128565	1.929480	0.261584	0.417317	0.519462	3.967784	5.277750	5.744255	0.632430	44										
20	0.005435	0.129425	1.928780	0.264040	0.437330	0.541194	3.967496	5.390314	5.853795	0.635315	42										
22	0.005805	0.130285	1.928080	0.266496	0.457343	0.562926	3.967208	5.502878	5.963335	0.638200	40										
24	0.006175	0.131145	1.927380	0.268952	0.477356	0.584658	3.966920	5.615442	6.072875	0.641085	38										
26	0.006545	0.132005	1.926680	0.271408	0.497369	0.606390	3.966632	5.728006	6.182415	0.643970	36										
28	0.006915	0.132865	1.925980	0.273864	0.517382	0.628122	3.966344	5.840568	6.291955	0.646855	34										
30	0.007285	0.133725	1.925280	0.276320	0.537395	0.649854	3.966056	5.953130	6.401495	0.649740	32										
32	0.007655	0.134585	1.924580	0.278776	0.557408	0.671586	3.965768	6.065692	6.511035	0.652625	30										
34	0.008025	0.135445	1.923880	0.281232	0.577421	0.693318	3.965480	6.178254	6.620575	0.655510	28										
36	0.008395	0.136305	1.923180	0.283688	0.597434	0.715050	3.965192	6.290816	6.730115	0.658395	26										
38	0.008765	0.137165	1.922480	0.286144	0.617447	0.736782	3.964904	6.403378	6.839655	0.661280	24										
40	0.009135	0.138025	1.921780	0.288600	0.637460	0.758514	3.964616	6.515940	6.949195	0.664165	22										
42	0.009505	0.138885	1.921080	0.291056	0.657473	0.780246	3.964328	6.628502	7.058735	0.667045	20										
44	0.009875	0.139745	1.920380	0.293512	0.677486	0.801978	3.964040	6.741064	7.168275	0.669930	18										
46	0.010245	0.140605	1.919680	0.295968	0.697499	0.823710	3.963752	6.853626	7.277815	0.672810	16										
48	0.010615	0.141465	1.918980	0.298424	0.717512	0.845442	3.963464	6.966188	7.387355	0.675695	14										
50	0.010985	0.142325	1.918280	0.300880	0.737525	0.867174	3.963176	7.078750	7.496895	0.678575	12										
52	0.011355	0.143185	1.917580	0.303336	0.757538	0.888906	3.962888	7.191312	7.606435	0.681455	10										
54	0.011725	0.144045	1.916880	0.305792	0.777551	0.910638	3.962600	7.303874	7.715975	0.684340	8										
56	0.012095	0.144905	1.916180	0.308248	0.797564	0.932370	3.962312	7.416436	7.825515	0.687225	6										
58	0.012465	0.145765	1.915480	0.310704	0.817577	0.954102	3.962024	7.528998	7.935055	0.690110	4										
60	0.012835	0.146625	1.914780	0.313160	0.837590	0.975834	3.961736	7.641560	8.044595	0.692995	2										
62	0.013205	0.147485	1.914080	0.315616	0.857603	0.997566	3.961448	7.754122	8.154135	0.695880	0										

Degrees and Minutes.	Measured Distance, or Hypothenuse, 1, 10, 100, 1000, or 100,000.				Measured Distance, or Hypothenuse, 2, 20, 200, 2000, or 200,000.				Measured Distance, or Hypothenuse, 3, 30, 300, 3000, or 300,000.				Measured Distance, or Hypothenuse, 4, 40, 400, 4000, or 400,000.				Measured Distance, or Hypothenuse, 5, 50, 500, 5000, or 500,000.				Degrees and Minutes.
	Distance from East or West.	Latitude of North or South.	Distance from East or West.	Latitude of North or South.	Distance from East or West.	Latitude of North or South.	Distance from East or West.	Latitude of North or South.	Distance from East or West.	Latitude of North or South.	Distance from East or West.	Latitude of North or South.	Distance from East or West.	Latitude of North or South.	Distance from East or West.	Latitude of North or South.	Distance from East or West.	Latitude of North or South.	Distance from East or West.	Latitude of North or South.	
2	0.990263	0.139718	1.980536	0.278249	2.970504	0.417619	3.961072	0.558996	4.951340	0.698565	5.941608	0.846134	6.931902	0.993610	7.923170	8.910038	9.892516	10.879594	11.869272	12.859550	2
4	0.990126	0.139748	1.980399	0.278493	2.970367	0.417863	3.960935	0.559240	4.951202	0.698810	5.941867	0.846385	6.932653	0.993865	7.924123	8.911051	9.893529	10.882697	11.873365	12.864633	4
6	0.990000	0.139778	1.980262	0.278737	2.970230	0.418107	3.960800	0.559484	4.951459	0.699055	5.942112	0.846630	6.933908	0.994120	7.925376	8.912300	9.895782	10.885950	11.876630	12.867882	6
8	0.989884	0.139808	1.980125	0.278981	2.970093	0.418351	3.960663	0.559728	4.951712	0.699300	5.942365	0.846875	6.934163	0.994375	7.926639	8.913492	9.897037	10.889205	11.879885	12.871135	8
10	0.989768	0.139838	1.980000	0.279225	2.969957	0.418595	3.960526	0.560000	4.951967	0.699545	5.942618	0.847120	6.934918	0.994630	7.927902	8.914681	9.898292	10.892460	11.883140	12.874388	10
12	0.989652	0.139868	1.979875	0.279469	2.969820	0.418839	3.960389	0.560244	4.952221	0.699790	5.942871	0.847365	6.935673	0.994885	7.929165	8.915870	9.899547	10.895715	11.886395	12.877641	12
14	0.989536	0.139898	1.979750	0.279713	2.969683	0.419083	3.960252	0.560488	4.952476	0.700035	5.943124	0.847610	6.936428	0.995140	7.930428	8.917059	9.900802	10.898980	11.889650	12.880894	14
16	0.989420	0.139928	1.979625	0.279957	2.969546	0.419327	3.960115	0.560732	4.952730	0.700280	5.943377	0.847855	6.937183	0.995395	7.931691	8.918248	9.902057	10.902235	11.892905	12.884147	16
18	0.989304	0.139958	1.979500	0.280201	2.969409	0.419571	3.960000	0.560976	4.952985	0.700525	5.943630	0.848100	6.937938	0.995650	7.932954	8.919437	9.903312	10.905490	11.896110	12.887400	18
20	0.989188	0.139988	1.979375	0.280445	2.969272	0.419815	3.959875	0.561220	4.953239	0.700770	5.943883	0.848345	6.938693	0.995905	7.934217	8.920626	9.904567	10.908745	11.899365	12.890653	20
22	0.989072	0.140018	1.979250	0.280689	2.969135	0.420059	3.959750	0.561464	4.953494	0.701015	5.944136	0.848590	6.939448	0.996160	7.935480	8.921815	9.905822	10.912000	11.902620	12.893906	22
24	0.988956	0.140048	1.979125	0.280933	2.969000	0.420303	3.959625	0.561708	4.953749	0.701260	5.944389	0.848835	6.940203	0.996415	7.936743	8.923004	9.907077	10.915255	11.905875	12.897159	24
26	0.988840	0.140078	1.979000	0.281177	2.968863	0.420547	3.959500	0.561952	4.954004	0.701505	5.944642	0.849080	6.940958	0.996670	7.938006	8.924193	9.908332	10.918510	11.909130	12.899412	26
28	0.988724	0.140108	1.978875	0.281421	2.968726	0.420791	3.959375	0.562196	4.954259	0.701750	5.944895	0.849325	6.941713	0.996925	7.939269	8.925382	9.909587	10.921765	11.912385	12.902665	28
30	0.988608	0.140138	1.978750	0.281665	2.968589	0.421035	3.959250	0.562440	4.954514	0.701995	5.945148	0.849570	6.942468	0.997180	7.940532	8.926571	9.910842	10.925020	11.915640	12.905918	30
32	0.988492	0.140168	1.978625	0.281909	2.968452	0.421279	3.959125	0.562684	4.954769	0.702240	5.945401	0.849815	6.943223	0.997435	7.941795	8.927760	9.912097	10.928275	11.918895	12.909171	32
34	0.988376	0.140198	1.978500	0.282153	2.968315	0.421523	3.959000	0.562928	4.955024	0.702485	5.945654	0.850060	6.943978	0.997690	7.943058	8.928949	9.913352	10.931530	11.922150	12.912424	34
36	0.988260	0.140228	1.978375	0.282397	2.968178	0.421767	3.958875	0.563172	4.955279	0.702730	5.945907	0.850305	6.944733	0.997945	7.944321	8.930138	9.914607	10.934785	11.925405	12.915677	36
38	0.988144	0.140258	1.978250	0.282641	2.968041	0.422011	3.958750	0.563416	4.955534	0.702975	5.946160	0.850550	6.945488	0.998200	7.945584	8.931327	9.915862	10.938040	11.928660	12.918930	38
40	0.988028	0.140288	1.978125	0.282885	2.967904	0.422255	3.958625	0.563660	4.955789	0.703220	5.946413	0.850795	6.946243	0.998455	7.946847	8.932516	9.917117	10.941295	11.931915	12.922183	40
42	0.987912	0.140318	1.978000	0.283129	2.967767	0.422499	3.958500	0.563904	4.956044	0.703465	5.946666	0.851040	6.947008	0.998710	7.948110	8.933705	9.918372	10.944550	11.935180	12.925436	42
44	0.987796	0.140348	1.977875	0.283373	2.967630	0.422743	3.958375	0.564148	4.956300	0.703710	5.946919	0.851285	6.947763	0.998965	7.949373	8.934894	9.919627	10.947805	11.938435	12.928689	44
46	0.987680	0.140378	1.977750	0.283617	2.967493	0.422987	3.958250	0.564392	4.956555	0.703955	5.947172	0.851530	6.948518	0.999220	7.950636	8.936083	9.920882	10.951060	11.941690	12.931942	46
48	0.987564	0.140408	1.977625	0.283861	2.967356	0.423231	3.958125	0.564636	4.956810	0.704200	5.947425	0.851775	6.949273	0.999475	7.951899	8.937272	9.922137	10.954315	11.944945	12.935195	48
50	0.987448	0.140438	1.977500	0.284105	2.967219	0.423475	3.958000	0.564880	4.957065	0.704445	5.947678	0.852020	6.950028	0.999730	7.953162	8.938461	9.923392	10.957570	11.948200	12.938448	50
52	0.987332	0.140468	1.977375	0.284349	2.967082	0.423719	3.957875	0.565124	4.957320	0.704690	5.947931	0.852265	6.950783	0.999985	7.954425	8.939650	9.924647	10.960825	11.951455	12.941701	52
54	0.987216	0.140498	1.977250	0.284593	2.966945	0.423963	3.957750	0.565368	4.957575	0.704935	5.948184	0.852510	6.951538	1.000240	7.955688	8.940839	9.925902	10.964080	11.954710	12.944954	54
56	0.987100	0.140528	1.977125	0.284837	2.966808	0.424207	3.957625	0.565612	4.957830	0.705180	5.948437	0.852755	6.952293	1.000495	7.956951	8.942028	9.927157	10.967335	11.957965	12.948207	56
58	0.986984	0.140558	1.977000	0.285081	2.966671	0.424451	3.957500	0.565856	4.958085	0.705425	5.948690	0.853000	6.953048	1.000750	7.958214	8.943217	9.928412	10.970590	11.961220	12.951460	58
60	0.986868	0.140588	1.976875	0.285325	2.966534	0.424695	3.957375	0.566100	4.958340	0.705670	5.948943	0.853245	6.953803	1.001005	7.959477	8.944406	9.929667	10.973845	11.964475	12.954713	60

Degrees and Minutes.	Measured Distance, or Hypothenuse, 1, 10, 100, 1000, 10,000, or 100,000.				Measured Distance, or Hypothenuse, 2, 20, 200, 2000, 20,000, or 200,000.				Measured Distance, or Hypothenuse, 3, 30, 300, 3000, 30,000, or 300,000.				Measured Distance, or Hypothenuse, 4, 40, 400, 4000, 40,000, or 400,000.				Measured Distance, or Hypothenuse, 5, 50, 500, 5000, 50,000, or 500,000.				Degrees and Minutes.
	Distance from North or South.	Latitude of Place.	Distance from North or South.	Latitude of Place.	Distance from North or South.	Latitude of Place.	Distance from North or South.	Latitude of Place.	Distance from North or South.	Latitude of Place.	Distance from North or South.	Latitude of Place.	Distance from North or South.	Latitude of Place.	Distance from North or South.	Latitude of Place.	Distance from North or South.	Latitude of Place.	Distance from North or South.	Latitude of Place.	
45	0.987688	0.159434	1.973376	0.313558	2.960064	0.468002	3.946752	0.595736	4.933440	0.723170	5.920158	0.850842	6.906840	0.978524	7.893208	8.877872	9.862536	10.847200	11.831864	12.816528	45
46	0.987597	0.157009	1.972501	0.311018	2.959251	0.471027	3.945983	0.593383	4.932670	0.720435	5.919115	0.848735	6.905420	0.977635	7.892270	8.876920	9.861570	10.846220	11.830880	12.815540	46
47	0.987413	0.154535	1.971626	0.308478	2.958501	0.474036	3.945233	0.590843	4.931920	0.717887	5.917365	0.846195	6.903680	0.976935	7.891520	8.876170	9.860820	10.845470	11.830130	12.814800	47
48	0.987231	0.152061	1.970751	0.305938	2.957751	0.477045	3.944483	0.588303	4.931210	0.715337	5.916615	0.843655	6.902930	0.976035	7.890670	8.875420	9.860070	10.844720	11.829680	12.814050	48
49	0.987050	0.149587	1.969876	0.303398	2.957001	0.480054	3.943733	0.585763	4.930500	0.712787	5.915965	0.841115	6.902180	0.975135	7.889820	8.874670	9.859320	10.843970	11.828930	12.813300	49
50	0.986871	0.147112	1.969001	0.300858	2.956251	0.483063	3.942983	0.583223	4.929790	0.710237	5.915320	0.838575	6.901430	0.974235	7.888970	8.873920	9.858570	10.843220	11.828180	12.812550	50
51	0.986697	0.144637	1.968126	0.298318	2.955501	0.486072	3.942233	0.580683	4.929040	0.707687	5.914675	0.836035	6.900680	0.973335	7.888120	8.873170	9.857820	10.842470	11.827430	12.811800	51
52	0.986529	0.142162	1.967251	0.295778	2.954751	0.489081	3.941483	0.578143	4.928290	0.705137	5.914030	0.833495	6.899930	0.972435	7.887270	8.872420	9.857070	10.841720	11.826780	12.811050	52
53	0.986360	0.139687	1.966376	0.293238	2.954001	0.492090	3.940733	0.575603	4.927540	0.702587	5.913380	0.830955	6.899180	0.971535	7.886420	8.871670	9.856320	10.840970	11.826030	12.810300	53
54	0.986199	0.137212	1.965501	0.290698	2.953251	0.495100	3.939983	0.573063	4.926790	0.700037	5.912730	0.828415	6.898430	0.970635	7.885570	8.870920	9.855570	10.840220	11.825280	12.809550	54
55	0.986038	0.134737	1.964626	0.288158	2.952501	0.498109	3.939233	0.570523	4.926040	0.697487	5.912080	0.825875	6.897680	0.969735	7.884720	8.870170	9.854820	10.839470	11.824530	12.808800	55
56	0.985880	0.132262	1.963751	0.285618	2.951751	0.501118	3.938483	0.567983	4.925290	0.694937	5.911430	0.823335	6.896930	0.968835	7.883870	8.869420	9.854070	10.838720	11.823780	12.808050	56
57	0.985729	0.129787	1.962876	0.283078	2.951001	0.504127	3.937733	0.565443	4.924540	0.692387	5.910780	0.820795	6.896180	0.967935	7.883020	8.868670	9.853320	10.837970	11.823030	12.807300	57
58	0.985578	0.127312	1.962001	0.280538	2.950251	0.507136	3.936983	0.562903	4.923790	0.689837	5.910130	0.818255	6.895430	0.967035	7.882170	8.867920	9.852570	10.837220	11.822280	12.806550	58
59	0.985429	0.124837	1.961126	0.277998	2.949501	0.510145	3.936233	0.560363	4.923040	0.687287	5.909480	0.815715	6.894680	0.966135	7.881320	8.867170	9.851820	10.836470	11.821530	12.805800	59
60	0.985280	0.122362	1.960251	0.275458	2.948751	0.513154	3.935483	0.557823	4.922290	0.684737	5.908830	0.813175	6.893930	0.965235	7.880470	8.866420	9.851070	10.835720	11.820780	12.805050	60

Lap- per and Re- g.	Measured Distance, or Hypothense, 1,10, 100, 10,000, or 100,000.				Measured Distance, or Hypothense, 2,20, 200, 20,000, or 200,000.				Measured Distance, or Hypothense, 3,30, 300, 30,000, or 300,000.				Measured Distance, or Hypothense, 4,40, 400, 40,000, or 400,000.				Measured Distance, or Hypothense, 5,50, 500, 50,000, or 500,000.			
	Distance from Plane of North or South	Distance from Plane of East or West	Distance from Plane of Merridian or Latitudo	Distance from Plane of South or North	Distance from Plane of East or West	Distance from Plane of Merridian or Latitudo	Distance from Plane of South or North	Distance from Plane of East or West	Distance from Plane of Merridian or Latitudo	Distance from Plane of South or North	Distance from Plane of East or West	Distance from Plane of Merridian or Latitudo	Distance from Plane of South or North	Distance from Plane of East or West	Distance from Plane of Merridian or Latitudo	Distance from Plane of South or North	Distance from Plane of East or West	Distance from Plane of Merridian or Latitudo	Distance from Plane of South or North	Distance from Plane of East or West
10	0.984507	0.173614	0.347236	2.954418	0.530044	0.3990225	0.684492	4.924055	0.893240	0.684492	4.924055	0.893240	0.684492	4.924055	0.893240	0.684492	4.924055	0.893240	0.684492	4.924055
20	0.984708	0.174221	0.347442	2.954118	0.529263	0.3988324	0.684884	4.923580	0.893580	0.3988324	0.684884	4.923580	0.893580	0.3988324	0.684884	4.923580	0.893580	0.3988324	0.684884	4.923580
30	0.984803	0.174763	0.347650	2.953815	0.528500	0.3985810	0.685272	4.923112	0.893872	0.3985810	0.685272	4.923112	0.893872	0.3985810	0.685272	4.923112	0.893872	0.3985810	0.685272	4.923112
40	0.984901	0.175308	0.347862	2.953510	0.527750	0.3983300	0.685664	4.922640	0.894160	0.3983300	0.685664	4.922640	0.894160	0.3983300	0.685664	4.922640	0.894160	0.3983300	0.685664	4.922640
50	0.985000	0.175854	0.348074	2.953204	0.527000	0.3980790	0.686056	4.922170	0.894450	0.3980790	0.686056	4.922170	0.894450	0.3980790	0.686056	4.922170	0.894450	0.3980790	0.686056	4.922170
60	0.985100	0.176401	0.348286	2.952898	0.526250	0.3978280	0.686448	4.921700	0.894740	0.3978280	0.686448	4.921700	0.894740	0.3978280	0.686448	4.921700	0.894740	0.3978280	0.686448	4.921700
70	0.985200	0.176948	0.348498	2.952592	0.525500	0.3975770	0.686840	4.921230	0.895030	0.3975770	0.686840	4.921230	0.895030	0.3975770	0.686840	4.921230	0.895030	0.3975770	0.686840	4.921230
80	0.985300	0.177495	0.348710	2.952286	0.524750	0.3973260	0.687232	4.920760	0.895320	0.3973260	0.687232	4.920760	0.895320	0.3973260	0.687232	4.920760	0.895320	0.3973260	0.687232	4.920760
90	0.985400	0.178042	0.348922	2.951980	0.524000	0.3970750	0.687624	4.920290	0.895610	0.3970750	0.687624	4.920290	0.895610	0.3970750	0.687624	4.920290	0.895610	0.3970750	0.687624	4.920290
100	0.985500	0.178589	0.349134	2.951674	0.523250	0.3968240	0.688016	4.919820	0.895900	0.3968240	0.688016	4.919820	0.895900	0.3968240	0.688016	4.919820	0.895900	0.3968240	0.688016	4.919820
110	0.985600	0.179136	0.349346	2.951368	0.522500	0.3965730	0.688408	4.919350	0.896190	0.3965730	0.688408	4.919350	0.896190	0.3965730	0.688408	4.919350	0.896190	0.3965730	0.688408	4.919350
120	0.985700	0.179683	0.349558	2.951062	0.521750	0.3963220	0.688800	4.918880	0.896480	0.3963220	0.688800	4.918880	0.896480	0.3963220	0.688800	4.918880	0.896480	0.3963220	0.688800	4.918880
130	0.985800	0.180230	0.349770	2.950756	0.521000	0.3960710	0.689192	4.918410	0.896770	0.3960710	0.689192	4.918410	0.896770	0.3960710	0.689192	4.918410	0.896770	0.3960710	0.689192	4.918410
140	0.985900	0.180777	0.349982	2.950450	0.520250	0.3958200	0.689584	4.917940	0.897060	0.3958200	0.689584	4.917940	0.897060	0.3958200	0.689584	4.917940	0.897060	0.3958200	0.689584	4.917940
150	0.986000	0.181324	0.350194	2.950144	0.519500	0.3955690	0.689976	4.917470	0.897350	0.3955690	0.689976	4.917470	0.897350	0.3955690	0.689976	4.917470	0.897350	0.3955690	0.689976	4.917470
160	0.986100	0.181871	0.350406	2.949838	0.518750	0.3953180	0.690368	4.917000	0.897640	0.3953180	0.690368	4.917000	0.897640	0.3953180	0.690368	4.917000	0.897640	0.3953180	0.690368	4.917000
170	0.986200	0.182418	0.350618	2.949532	0.518000	0.3950670	0.690760	4.916530	0.897930	0.3950670	0.690760	4.916530	0.897930	0.3950670	0.690760	4.916530	0.897930	0.3950670	0.690760	4.916530
180	0.986300	0.182965	0.350830	2.949226	0.517250	0.3948160	0.691152	4.916060	0.898220	0.3948160	0.691152	4.916060	0.898220	0.3948160	0.691152	4.916060	0.898220	0.3948160	0.691152	4.916060
190	0.986400	0.183512	0.351042	2.948920	0.516500	0.3945650	0.691544	4.915590	0.898510	0.3945650	0.691544	4.915590	0.898510	0.3945650	0.691544	4.915590	0.898510	0.3945650	0.691544	4.915590
200	0.986500	0.184059	0.351254	2.948614	0.515750	0.3943140	0.691936	4.915120	0.898800	0.3943140	0.691936	4.915120	0.898800	0.3943140	0.691936	4.915120	0.898800	0.3943140	0.691936	4.915120
210	0.986600	0.184606	0.351466	2.948308	0.515000	0.3940630	0.692328	4.914650	0.899090	0.3940630	0.692328	4.914650	0.899090	0.3940630	0.692328	4.914650	0.899090	0.3940630	0.692328	4.914650
220	0.986700	0.185153	0.351678	2.948002	0.514250	0.3938120	0.692720	4.914180	0.899380	0.3938120	0.692720	4.914180	0.899380	0.3938120	0.692720	4.914180	0.899380	0.3938120	0.692720	4.914180
230	0.986800	0.185700	0.351890	2.947696	0.513500	0.3935610	0.693112	4.913710	0.899670	0.3935610	0.693112	4.913710	0.899670	0.3935610	0.693112	4.913710	0.899670	0.3935610	0.693112	4.913710
240	0.986900	0.186247	0.352102	2.947390	0.512750	0.3933100	0.693504	4.913240	0.899960	0.3933100	0.693504	4.913240	0.899960	0.3933100	0.693504	4.913240	0.899960	0.3933100	0.693504	4.913240
250	0.987000	0.186794	0.352314	2.947084	0.512000	0.3930590	0.693896	4.912770	0.900250	0.3930590	0.693896	4.912770	0.900250	0.3930590	0.693896	4.912770	0.900250	0.3930590	0.693896	4.912770
260	0.987100	0.187341	0.352526	2.946778	0.511250	0.3928080	0.694288	4.912300	0.900540	0.3928080	0.694288	4.912300	0.900540	0.3928080	0.694288	4.912300	0.900540	0.3928080	0.694288	4.912300
270	0.987200	0.187888	0.352738	2.946472	0.510500	0.3925570	0.694680	4.911830	0.900830	0.3925570	0.694680	4.911830	0.900830	0.3925570	0.694680	4.911830	0.900830	0.3925570	0.694680	4.911830
280	0.987300	0.188435	0.352950	2.946166	0.509750	0.3923060	0.695072	4.911360	0.901120	0.3923060	0.695072	4.911360	0.901120	0.3923060	0.695072	4.911360	0.901120	0.3923060	0.695072	4.911360
290	0.987400	0.188982	0.353162	2.945860	0.509000	0.3920550	0.695464	4.910890	0.901410	0.3920550	0.695464	4.910890	0.901410	0.3920550	0.695464	4.910890	0.901410	0.3920550	0.695464	4.910890
300	0.987500	0.189529	0.353374	2.945554	0.508250	0.3918040	0.695856	4.910420	0.901700	0.3918040	0.695856	4.910420	0.901700	0.3918040	0.695856	4.910420	0.901700	0.3918040	0.695856	4.910420
310	0.987600	0.190076	0.353586	2.945248	0.507500	0.3915530	0.696248	4.910000	0.902000	0.3915530	0.696248	4.910000	0.902000	0.3915530	0.696248	4.910000	0.902000	0.3915530	0.696248	4.910000
320	0.987700	0.190623	0.353798	2.944942	0.506750	0.3913020	0.696640	4.909530	0.902300	0.3913020	0.696640	4.909530	0.902300	0.3913020	0.696640	4.909530	0.902300	0.3913020	0.696640	4.909530
330	0.987800	0.191170	0.354010	2.944636	0.506000	0.3910510	0.697032	4.909060	0.902600	0.3910510	0.697032	4.909060	0.902600	0.3910510	0.697032	4.909060	0.902600	0.3910510	0.697032	4.909060
340	0.987900	0.191717	0.354222	2.944330	0.505250	0.3908000	0.697424	4.908590	0.902900	0.3908000	0.697424	4.908590	0.902900	0.3908000	0.697424	4.908590	0.902900	0.3908000	0.697424	4.908590
350	0.988000	0.192264	0.354434	2.944024	0.504500	0.3905490	0.697816	4.908120	0.903200	0.3905490	0.697816	4.908120	0.903200	0.3905490	0.697816	4.908120	0.903200	0.3905490	0.697816	4.908120
360	0.988100	0.192811	0.354646	2.943718	0.503750	0.3902980	0.698208	4.907650	0.903500	0.3902980	0.698208	4.907650	0.903500	0.3902980	0.698208	4.907650	0.903500	0.3902980	0.698208	4.907650
370	0.988200	0.193358	0.354858	2.943412	0.503000	0.3900470	0.698600	4.907180	0.903800	0.3900470	0.698600	4.907180	0.903800	0.3900470	0.698600	4.907180	0.903800	0.3900470	0.698600	4.907180
380	0.988300	0.193905	0.355070	2.943106	0.502250	0.3897960	0.698992	4.906710	0.904100	0.3897960	0.698992	4.906710	0.904100	0.3897960	0.698992	4.906710	0.904100	0.3897960	0.698992	4.906710
390	0.988400	0.194452	0.355282	2.942800	0.501500	0.3895450	0.699384	4.906240	0.904400	0.3895450	0.699384	4.906240	0.904400	0.3895450	0.699384	4.906240	0.904400	0.3895450	0.699384	4.906240
400	0.988500	0.195000	0.355494	2.942494	0.500750	0.3892940	0.699776	4.905770	0.904700	0.3892940	0.699776	4.905770	0.904700	0.3892940	0.699776	4.905770	0.904700	0.3892940	0.699776	4.905770
410	0.988600	0.195547	0.355706	2.942188	0.500000	0.3890430	0.700168	4.905300	0.905000	0.3890430	0.700168	4.905300	0.905000	0.3890430	0.700168	4.905300	0.905000	0.3890430	0.700168	4.905300
420	0.988700</																			

Degrees and Minutes	Measured Distance, or Hypothenuse, 1, 10, 100, 1000, 10,000, or 100,000.				Measured Distance, or Hypothenuse, 2, 20, 200, 2000, 20,000, or 200,000.				Measured Distance, or Hypothenuse, 4, 40, 400, 4000, 40,000, or 400,000.				Measured Distance, or Hypothenuse, 6, 60, 600, 6000, 60,000, or 600,000.				Degrees and Minutes
	Distance from Meridian, or South or North.	Distance from Meridian, or East or West.	Distance from Meridian, or South or North.	Distance from Meridian, or East or West.	Distance from Meridian, or South or North.	Distance from Meridian, or East or West.	Distance from Meridian, or South or North.	Distance from Meridian, or East or West.	Distance from Meridian, or South or North.	Distance from Meridian, or East or West.	Distance from Meridian, or South or North.	Distance from Meridian, or East or West.	Distance from Meridian, or South or North.	Distance from Meridian, or East or West.	Distance from Meridian, or South or North.	Distance from Meridian, or East or West.	
11	0.06187	0.19080	1.96354	0.38131	2.94480	0.57247	3.92608	0.76326	4.90835	0.95405	5.89055	6.87280	7.85505	8.83730	9.81955	10.80180	59
12	0.06187	0.19130	1.96354	0.38276	2.94480	0.57410	3.92608	0.76520	4.90835	0.95505	5.89155	6.87380	7.85605	8.83830	9.82055	10.80280	58
13	0.06187	0.19180	1.96354	0.38421	2.94480	0.57570	3.92608	0.76670	4.90835	0.95605	5.89255	6.87480	7.85705	8.83930	9.82155	10.80380	57
14	0.06187	0.19230	1.96354	0.38566	2.94480	0.57730	3.92608	0.76820	4.90835	0.95705	5.89355	6.87580	7.85805	8.84030	9.82255	10.80480	56
15	0.06187	0.19280	1.96354	0.38711	2.94480	0.57890	3.92608	0.76970	4.90835	0.95805	5.89455	6.87680	7.85905	8.84130	9.82355	10.80580	55
16	0.06187	0.19330	1.96354	0.38856	2.94480	0.58050	3.92608	0.77120	4.90835	0.95905	5.89555	6.87780	7.86005	8.84230	9.82455	10.80680	54
17	0.06187	0.19380	1.96354	0.39001	2.94480	0.58210	3.92608	0.77270	4.90835	0.96005	5.89655	6.87880	7.86105	8.84330	9.82555	10.80780	53
18	0.06187	0.19430	1.96354	0.39146	2.94480	0.58365	3.92608	0.77420	4.90835	0.96105	5.89755	6.87980	7.86205	8.84430	9.82655	10.80880	52
19	0.06187	0.19480	1.96354	0.39291	2.94480	0.58520	3.92608	0.77570	4.90835	0.96205	5.89855	6.88080	7.86305	8.84530	9.82755	10.80980	51
20	0.06187	0.19530	1.96354	0.39436	2.94480	0.58675	3.92608	0.77720	4.90835	0.96305	5.89955	6.88180	7.86405	8.84630	9.82855	10.81080	50
21	0.06187	0.19580	1.96354	0.39581	2.94480	0.58830	3.92608	0.77870	4.90835	0.96405	5.90055	6.88280	7.86505	8.84730	9.82955	10.81180	49
22	0.06187	0.19630	1.96354	0.39726	2.94480	0.58985	3.92608	0.78020	4.90835	0.96505	5.90155	6.88380	7.86605	8.84830	9.83055	10.81280	48
23	0.06187	0.19680	1.96354	0.39871	2.94480	0.59140	3.92608	0.78170	4.90835	0.96605	5.90255	6.88480	7.86705	8.84930	9.83155	10.81380	47
24	0.06187	0.19730	1.96354	0.40016	2.94480	0.59295	3.92608	0.78320	4.90835	0.96705	5.90355	6.88580	7.86805	8.85030	9.83255	10.81480	46
25	0.06187	0.19780	1.96354	0.40161	2.94480	0.59450	3.92608	0.78470	4.90835	0.96805	5.90455	6.88680	7.86905	8.85130	9.83355	10.81580	45
26	0.06187	0.19830	1.96354	0.40306	2.94480	0.59605	3.92608	0.78620	4.90835	0.96905	5.90555	6.88780	7.87005	8.85230	9.83455	10.81680	44
27	0.06187	0.19880	1.96354	0.40451	2.94480	0.59760	3.92608	0.78770	4.90835	0.97005	5.90655	6.88880	7.87105	8.85330	9.83555	10.81780	43
28	0.06187	0.19930	1.96354	0.40596	2.94480	0.59915	3.92608	0.78920	4.90835	0.97105	5.90755	6.88980	7.87205	8.85430	9.83655	10.81880	42
29	0.06187	0.19980	1.96354	0.40741	2.94480	0.60070	3.92608	0.79070	4.90835	0.97205	5.90855	6.89080	7.87305	8.85530	9.83755	10.81980	41
30	0.06187	0.20030	1.96354	0.40886	2.94480	0.60225	3.92608	0.79220	4.90835	0.97305	5.90955	6.89180	7.87405	8.85630	9.83855	10.82080	40
31	0.06187	0.20080	1.96354	0.41031	2.94480	0.60380	3.92608	0.79370	4.90835	0.97405	5.91055	6.89280	7.87505	8.85730	9.83955	10.82180	39
32	0.06187	0.20130	1.96354	0.41176	2.94480	0.60535	3.92608	0.79520	4.90835	0.97505	5.91155	6.89380	7.87605	8.85830	9.84055	10.82280	38
33	0.06187	0.20180	1.96354	0.41321	2.94480	0.60690	3.92608	0.79670	4.90835	0.97605	5.91255	6.89480	7.87705	8.85930	9.84155	10.82380	37
34	0.06187	0.20230	1.96354	0.41466	2.94480	0.60845	3.92608	0.79820	4.90835	0.97705	5.91355	6.89580	7.87805	8.86030	9.84255	10.82480	36
35	0.06187	0.20280	1.96354	0.41611	2.94480	0.61000	3.92608	0.79970	4.90835	0.97805	5.91455	6.89680	7.87905	8.86130	9.84355	10.82580	35
36	0.06187	0.20330	1.96354	0.41756	2.94480	0.61155	3.92608	0.80120	4.90835	0.97905	5.91555	6.89780	7.88005	8.86230	9.84455	10.82680	34
37	0.06187	0.20380	1.96354	0.41901	2.94480	0.61310	3.92608	0.80270	4.90835	0.98005	5.91655	6.89880	7.88105	8.86330	9.84555	10.82780	33
38	0.06187	0.20430	1.96354	0.42046	2.94480	0.61465	3.92608	0.80420	4.90835	0.98105	5.91755	6.89980	7.88205	8.86430	9.84655	10.82880	32
39	0.06187	0.20480	1.96354	0.42191	2.94480	0.61620	3.92608	0.80570	4.90835	0.98205	5.91855	6.89080	7.88305	8.86530	9.84755	10.82980	31
40	0.06187	0.20530	1.96354	0.42336	2.94480	0.61775	3.92608	0.80720	4.90835	0.98305	5.91955	6.89180	7.88405	8.86630	9.84855	10.83080	30
41	0.06187	0.20580	1.96354	0.42481	2.94480	0.61930	3.92608	0.80870	4.90835	0.98405	5.92055	6.89280	7.88505	8.86730	9.84955	10.83180	29
42	0.06187	0.20630	1.96354	0.42626	2.94480	0.62085	3.92608	0.81020	4.90835	0.98505	5.92155	6.89380	7.88605	8.86830	9.85055	10.83280	28
43	0.06187	0.20680	1.96354	0.42771	2.94480	0.62240	3.92608	0.81170	4.90835	0.98605	5.92255	6.89480	7.88705	8.86930	9.85155	10.83380	27
44	0.06187	0.20730	1.96354	0.42916	2.94480	0.62395	3.92608	0.81320	4.90835	0.98705	5.92355	6.89580	7.88805	8.87030	9.85255	10.83480	26
45	0.06187	0.20780	1.96354	0.43061	2.94480	0.62550	3.92608	0.81470	4.90835	0.98805	5.92455	6.89680	7.88905	8.87130	9.85355	10.83580	25
46	0.06187	0.20830	1.96354	0.43206	2.94480	0.62705	3.92608	0.81620	4.90835	0.98905	5.92555	6.89780	7.89005	8.87230	9.85455	10.83680	24
47	0.06187	0.20880	1.96354	0.43351	2.94480	0.62860	3.92608	0.81770	4.90835	0.99005	5.92655	6.89880	7.89105	8.87330	9.85555	10.83780	23
48	0.06187	0.20930	1.96354	0.43496	2.94480	0.63015	3.92608	0.81920	4.90835	0.99105	5.92755	6.89980	7.89205	8.87430	9.85655	10.83880	22
49	0.06187	0.20980	1.96354	0.43641	2.94480	0.63170	3.92608	0.82070	4.90835	0.99205	5.92855	6.90080	7.89305	8.87530	9.85755	10.83980	21
50	0.06187	0.21030	1.96354	0.43786	2.94480	0.63325	3.92608	0.82220	4.90835	0.99305	5.92955	6.90180	7.89405	8.87630	9.85855	10.84080	20
51	0.06187	0.21080	1.96354	0.43931	2.94480	0.63480	3.92608	0.82370	4.90835	0.99405	5.93055	6.90280	7.89505	8.87730	9.85955	10.84180	19
52	0.06187	0.21130	1.96354	0.44076	2.94480	0.63635	3.92608	0.82520	4.90835	0.99505	5.93155	6.90380	7.89605	8.87830	9.86055	10.84280	18
53	0.06187	0.21180	1.96354	0.44221	2.94480	0.63790	3.92608	0.82670	4.90835	0.99605	5.93255	6.90480	7.89705	8.87930	9.86155	10.84380	17
54	0.06187	0.21230	1.96354	0.44366	2.94480	0.63945	3.92608	0.82820	4.90835	0.99705	5.93355	6.90580	7.89805	8.88030	9.86255	10.84480	16
55	0.06187	0.21280	1.96354	0.44511	2.94480	0.64100	3.92608	0.82970	4.90835	0.99805	5.93455	6.90680	7.89905	8.88130	9.86355	10.84580	15
56	0.06187	0.21330	1.96354	0.44656	2.94480	0.64255	3.92608	0.83120	4.90835	0.99905	5.93555	6.90780	7.90005	8.88230	9.86455	10.84680	14
57	0.06187	0.21380	1.96354	0.44801	2.94480	0.64410	3.92608	0.83270	4.90835	1.00005	5.93655	6.90880	7.90105	8.88330	9.86555	10.84780	13
58	0.06187	0.21430	1.96354	0.44946	2.94480	0.64565	3.92608	0.83420	4.90835	1.00105	5.93755	6.90980	7.90205	8.88430	9.86655	10.84880	12
59	0.06187	0.21480	1.96354	0.45091	2.94480	0.64720	3.92608	0.83570	4.90835	1.00205	5.93855	6.91080	7.90305	8.88530	9.86755	10.84980	11
60	0.06187	0.21530	1.96354	0.45236	2.94480	0.64875	3.92608	0.83720	4.90835	1.00305	5.93955	6.91180	7.90405	8.88630	9.86855	10.85080	10



Degrees and Minutes.	Measured Distance, or Hypothenuse, 1, 10, 100, 1000, 10,000, or 100,000.				Measured Distance, or Hypothenuse, 3, 30, 300, 3000, 30,000, or 300,000.				Measured Distance, or Hypothenuse, 4, 40, 400, 4000, 40,000, or 400,000.				Measured Distance, or Hypothenuse, 5, 50, 500, 5000, 50,000, or 500,000.				Degrees and Minutes.
	Distance from North or East.	Latitude from North or East.	Distance from North or East.	Distance from North or East.	Distance from North or East.	Latitude from North or East.	Distance from North or East.	Distance from North or East.	Distance from North or East.	Latitude from North or East.	Distance from North or East.	Distance from North or East.	Distance from North or East.	Latitude from North or East.	Distance from North or East.	Distance from North or East.	
13	0.974370	0.224957	1.948740	0.442902	2.923110	0.674853	3.897480	0.899804	4.871650	1.124755	60						
14	0.974239	0.224957	1.948475	0.451034	2.922717	0.676551	3.896958	0.902068	4.871195	1.124755	58						
15	0.974107	0.224957	1.948210	0.459166	2.922324	0.678252	3.896528	0.904336	4.870735	1.124755	56						
16	0.973976	0.224957	1.947945	0.467298	2.921931	0.679953	3.896094	0.906604	4.869880	1.124755	54						
17	0.973845	0.224957	1.947680	0.475430	2.921538	0.681651	3.895660	0.908863	4.869415	1.124755	52						
18	0.973714	0.224957	1.947415	0.483562	2.921145	0.683352	3.895226	0.911136	4.868955	1.124755	50						
19	0.973583	0.224957	1.947150	0.491694	2.920752	0.685053	3.894791	0.913407	4.868495	1.124755	48						
20	0.973452	0.224957	1.946885	0.500000	2.920359	0.686754	3.894356	0.915678	4.868035	1.124755	46						
21	0.973321	0.224957	1.946620	0.508132	2.919966	0.688455	3.893921	0.917949	4.867575	1.124755	44						
22	0.973190	0.224957	1.946355	0.516264	2.919573	0.690156	3.893486	0.920220	4.867115	1.124755	42						
23	0.973059	0.224957	1.946090	0.524396	2.919180	0.691857	3.893051	0.922491	4.866655	1.124755	40						
24	0.972928	0.224957	1.945825	0.532528	2.918787	0.693558	3.892616	0.924762	4.866195	1.124755	38						
25	0.972797	0.224957	1.945560	0.540660	2.918394	0.695259	3.892181	0.927033	4.865735	1.124755	36						
26	0.972666	0.224957	1.945295	0.548792	2.918001	0.696960	3.891746	0.929304	4.865275	1.124755	34						
27	0.972535	0.224957	1.945030	0.556924	2.917608	0.698661	3.891311	0.931575	4.864815	1.124755	32						
28	0.972404	0.224957	1.944765	0.565056	2.917215	0.700335	3.890876	0.933846	4.864355	1.124755	30						
29	0.972273	0.224957	1.944500	0.573188	2.916822	0.702033	3.890441	0.936117	4.863895	1.124755	28						
30	0.972142	0.224957	1.944235	0.581320	2.916429	0.703734	3.890006	0.938388	4.863435	1.124755	26						
31	0.972011	0.224957	1.943970	0.589452	2.916036	0.705435	3.889571	0.940659	4.862975	1.124755	24						
32	0.971880	0.224957	1.943705	0.597584	2.915643	0.707136	3.889136	0.942930	4.862515	1.124755	22						
33	0.971749	0.224957	1.943440	0.605716	2.915250	0.708837	3.888701	0.945201	4.862055	1.124755	20						
34	0.971618	0.224957	1.943175	0.613848	2.914857	0.710538	3.888266	0.947472	4.861595	1.124755	18						
35	0.971487	0.224957	1.942910	0.621980	2.914464	0.712239	3.887831	0.949743	4.861135	1.124755	16						
36	0.971356	0.224957	1.942645	0.630112	2.914071	0.713940	3.887396	0.952014	4.860675	1.124755	14						
37	0.971225	0.224957	1.942380	0.638244	2.913678	0.715641	3.886961	0.954285	4.860215	1.124755	12						
38	0.971094	0.224957	1.942115	0.646376	2.913285	0.717342	3.886526	0.956556	4.859755	1.124755	10						
39	0.970963	0.224957	1.941850	0.654508	2.912892	0.719043	3.886091	0.958827	4.859295	1.124755	8						
40	0.970832	0.224957	1.941585	0.662640	2.912500	0.720744	3.885656	0.961098	4.858835	1.124755	6						
41	0.970701	0.224957	1.941320	0.670772	2.912107	0.722445	3.885221	0.963369	4.858375	1.124755	4						
42	0.970570	0.224957	1.941055	0.678904	2.911714	0.724146	3.884786	0.965640	4.857915	1.124755	2						
43	0.970439	0.224957	1.940790	0.687036	2.911321	0.725847	3.884351	0.967911	4.857455	1.124755	0						
44	0.970308	0.224957	1.940525	0.695168	2.910928	0.727548	3.883916	0.970182	4.856995	1.124755							
45	0.970177	0.224957	1.940260	0.703300	2.910535	0.729249	3.883481	0.972453	4.856535	1.124755							
46	0.970046	0.224957	1.940000	0.711432	2.910142	0.730950	3.883046	0.974724	4.856075	1.124755							
47	0.969915	0.224957	1.939735	0.719564	2.909749	0.732651	3.882611	0.976995	4.855615	1.124755							
48	0.969784	0.224957	1.939470	0.727696	2.909356	0.734352	3.882176	0.979266	4.855155	1.124755							
49	0.969653	0.224957	1.939205	0.735828	2.908963	0.736053	3.881741	0.981537	4.854695	1.124755							
50	0.969522	0.224957	1.938940	0.743960	2.908570	0.737754	3.881306	0.983808	4.854235	1.124755							
51	0.969391	0.224957	1.938675	0.752092	2.908177	0.739455	3.880871	0.986079	4.853775	1.124755							
52	0.969260	0.224957	1.938410	0.760224	2.907784	0.741156	3.880436	0.988350	4.853315	1.124755							
53	0.969129	0.224957	1.938145	0.768356	2.907391	0.742857	3.880001	0.990621	4.852855	1.124755							
54	0.968998	0.224957	1.937880	0.776488	2.907000	0.744558	3.879566	0.992892	4.852395	1.124755							
55	0.968867	0.224957	1.937615	0.784620	2.906607	0.746259	3.879131	0.995163	4.851935	1.124755							
56	0.968736	0.224957	1.937350	0.792752	2.906214	0.747960	3.878696	0.997434	4.851475	1.124755							
57	0.968605	0.224957	1.937085	0.800884	2.905821	0.749661	3.878261	0.999705	4.851015	1.124755							
58	0.968474	0.224957	1.936820	0.809016	2.905428	0.751362	3.877826	1.001976	4.850555	1.124755							
59	0.968343	0.224957	1.936555	0.817148	2.905035	0.753063	3.877391	1.004247	4.850095	1.124755							
60	0.968212	0.224957	1.936290	0.825280	2.904642	0.754764	3.876956	1.006518	4.849635	1.124755							

### TRAVERSE TABLES.

[illegible]



Differences and Distances.	Measured Distances, or Hypotheses, 1, 10, 100, 1,000, 10,000, or 100,000.				Measured Distances, or Hypotheses, 1, 20, 200, 2,000, 20,000, or 200,000.				Measured Distances, or Hypotheses, 1, 30, 300, 3,000, 30,000, or 300,000.				Measured Distances, or Hypotheses, 1, 40, 400, 4,000, 40,000, or 400,000.				Measured Distances, or Hypotheses, 1, 50, 500, 5,000, 50,000, or 500,000.			
	From East or South.	From East or North.	Distance.	Latitude, or South or North.	From East or South.	From East or North.	Distance.	Latitude, or South or North.	From East or South.	From East or North.	Distance.	Latitude, or South or North.	From East or South.	From East or North.	Distance.	Latitude, or South or North.	From East or South.	From East or North.	Distance.	Latitude, or South or North.
1	0.965925	0.258319	0.965925	1.931800	0.517038	0.517038	2.897775	0.776477	3.863700	1.035272	1.035272	9.282276	4.898825	1.284085	60					
2	0.965775	0.258312	0.965775	1.931350	0.516752	0.516752	2.897325	0.776133	3.863100	1.035272	1.035272	9.282276	4.898825	1.284085	59					
3	0.965625	0.258304	0.965625	1.930900	0.516466	0.516466	2.896875	0.775895	3.862496	1.035272	1.035272	9.282276	4.898825	1.284085	58					
4	0.965475	0.258296	0.965475	1.930450	0.516180	0.516180	2.896425	0.775656	3.861892	1.035272	1.035272	9.282276	4.898825	1.284085	57					
5	0.965325	0.258288	0.965325	1.930000	0.515894	0.515894	2.895975	0.775417	3.861288	1.035272	1.035272	9.282276	4.898825	1.284085	56					
6	0.965175	0.258280	0.965175	1.929550	0.515608	0.515608	2.895525	0.775178	3.860684	1.035272	1.035272	9.282276	4.898825	1.284085	55					
7	0.965025	0.258272	0.965025	1.929100	0.515322	0.515322	2.895075	0.774939	3.860080	1.035272	1.035272	9.282276	4.898825	1.284085	54					
8	0.964875	0.258264	0.964875	1.928650	0.515036	0.515036	2.894625	0.774700	3.859476	1.035272	1.035272	9.282276	4.898825	1.284085	53					
9	0.964725	0.258256	0.964725	1.928200	0.514750	0.514750	2.894175	0.774461	3.858872	1.035272	1.035272	9.282276	4.898825	1.284085	52					
10	0.964575	0.258248	0.964575	1.927750	0.514464	0.514464	2.893725	0.774222	3.858268	1.035272	1.035272	9.282276	4.898825	1.284085	51					
11	0.964425	0.258240	0.964425	1.927300	0.514178	0.514178	2.893275	0.773983	3.857664	1.035272	1.035272	9.282276	4.898825	1.284085	50					
12	0.964275	0.258232	0.964275	1.926850	0.513892	0.513892	2.892825	0.773744	3.857060	1.035272	1.035272	9.282276	4.898825	1.284085	49					
13	0.964125	0.258224	0.964125	1.926400	0.513606	0.513606	2.892375	0.773505	3.856456	1.035272	1.035272	9.282276	4.898825	1.284085	48					
14	0.963975	0.258216	0.963975	1.925950	0.513320	0.513320	2.891925	0.773266	3.855852	1.035272	1.035272	9.282276	4.898825	1.284085	47					
15	0.963825	0.258208	0.963825	1.925500	0.513034	0.513034	2.891475	0.773027	3.855248	1.035272	1.035272	9.282276	4.898825	1.284085	46					
16	0.963675	0.258200	0.963675	1.925050	0.512748	0.512748	2.891025	0.772788	3.854644	1.035272	1.035272	9.282276	4.898825	1.284085	45					
17	0.963525	0.258192	0.963525	1.924600	0.512462	0.512462	2.890575	0.772549	3.854040	1.035272	1.035272	9.282276	4.898825	1.284085	44					
18	0.963375	0.258184	0.963375	1.924150	0.512176	0.512176	2.890125	0.772310	3.853436	1.035272	1.035272	9.282276	4.898825	1.284085	43					
19	0.963225	0.258176	0.963225	1.923700	0.511890	0.511890	2.889675	0.772071	3.852832	1.035272	1.035272	9.282276	4.898825	1.284085	42					
20	0.963075	0.258168	0.963075	1.923250	0.511604	0.511604	2.889225	0.771832	3.852228	1.035272	1.035272	9.282276	4.898825	1.284085	41					
21	0.962925	0.258160	0.962925	1.922800	0.511318	0.511318	2.888775	0.771593	3.851624	1.035272	1.035272	9.282276	4.898825	1.284085	40					
22	0.962775	0.258152	0.962775	1.922350	0.511032	0.511032	2.888325	0.771354	3.851020	1.035272	1.035272	9.282276	4.898825	1.284085	39					
23	0.962625	0.258144	0.962625	1.921900	0.510746	0.510746	2.887875	0.771115	3.850416	1.035272	1.035272	9.282276	4.898825	1.284085	38					
24	0.962475	0.258136	0.962475	1.921450	0.510460	0.510460	2.887425	0.770876	3.849812	1.035272	1.035272	9.282276	4.898825	1.284085	37					
25	0.962325	0.258128	0.962325	1.921000	0.510174	0.510174	2.886975	0.770637	3.849208	1.035272	1.035272	9.282276	4.898825	1.284085	36					
26	0.962175	0.258120	0.962175	1.920550	0.509888	0.509888	2.886525	0.770398	3.848604	1.035272	1.035272	9.282276	4.898825	1.284085	35					
27	0.962025	0.258112	0.962025	1.920100	0.509602	0.509602	2.886075	0.770159	3.848000	1.035272	1.035272	9.282276	4.898825	1.284085	34					
28	0.961875	0.258104	0.961875	1.919650	0.509316	0.509316	2.885625	0.769920	3.847396	1.035272	1.035272	9.282276	4.898825	1.284085	33					
29	0.961725	0.258096	0.961725	1.919200	0.509030	0.509030	2.885175	0.769681	3.846792	1.035272	1.035272	9.282276	4.898825	1.284085	32					
30	0.961575	0.258088	0.961575	1.918750	0.508744	0.508744	2.884725	0.769442	3.846188	1.035272	1.035272	9.282276	4.898825	1.284085	31					
31	0.961425	0.258080	0.961425	1.918300	0.508458	0.508458	2.884275	0.769203	3.845584	1.035272	1.035272	9.282276	4.898825	1.284085	30					
32	0.961275	0.258072	0.961275	1.917850	0.508172	0.508172	2.883825	0.768964	3.844980	1.035272	1.035272	9.282276	4.898825	1.284085	29					
33	0.961125	0.258064	0.961125	1.917400	0.507886	0.507886	2.883375	0.768725	3.844376	1.035272	1.035272	9.282276	4.898825	1.284085	28					
34	0.960975	0.258056	0.960975	1.916950	0.507600	0.507600	2.882925	0.768486	3.843772	1.035272	1.035272	9.282276	4.898825	1.284085	27					
35	0.960825	0.258048	0.960825	1.916500	0.507314	0.507314	2.882475	0.768247	3.843168	1.035272	1.035272	9.282276	4.898825	1.284085	26					
36	0.960675	0.258040	0.960675	1.916050	0.507028	0.507028	2.882025	0.768008	3.842564	1.035272	1.035272	9.282276	4.898825	1.284085	25					
37	0.960525	0.258032	0.960525	1.915600	0.506742	0.506742	2.881575	0.767769	3.841960	1.035272	1.035272	9.282276	4.898825	1.284085	24					
38	0.960375	0.258024	0.960375	1.915150	0.506456	0.506456	2.881125	0.767530	3.841356	1.035272	1.035272	9.282276	4.898825	1.284085	23					
39	0.960225	0.258016	0.960225	1.914700	0.506170	0.506170	2.880675	0.767291	3.840752	1.035272	1.035272	9.282276	4.898825	1.284085	22					
40	0.960075	0.258008	0.960075	1.914250	0.505884	0.505884	2.880225	0.767052	3.840148	1.035272	1.035272	9.282276	4.898825	1.284085	21					
41	0.959925	0.258000	0.959925	1.913800	0.505598	0.505598	2.879775	0.766813	3.839544	1.035272	1.035272	9.282276	4.898825	1.284085	20					
42	0.959775	0.257992	0.959775	1.913350	0.505312	0.505312	2.879325	0.766574	3.838940	1.035272	1.035272	9.282276	4.898825	1.284085	19					
43	0.959625	0.257984	0.959625	1.912900	0.505026	0.505026	2.878875	0.766335	3.838336	1.035272	1.035272	9.282276	4.898825	1.284085	18					
44	0.959475	0.257976	0.959475	1.912450	0.504740	0.504740	2.878425	0.766096	3.837732	1.035272	1.035272	9.282276	4.898825	1.284085	17					
45	0.959325	0.257968	0.959325	1.912000	0.504454	0.504454	2.877975	0.765857	3.837128	1.035272	1.035272	9.282276	4.898825	1.284085	16					
46	0.959175	0.257960	0.959175	1.911550	0.504168	0.504168	2.877525	0.765618	3.836524	1.035272	1.035272	9.282276	4.898825	1.284085	15					
47	0.959025	0.257952	0.959025	1.911100	0.503882	0.503882	2.877075	0.765379	3.835920	1.035272	1.035272	9.282276	4.898825	1.284085	14					
48	0.958875	0.257944	0.958875	1.910650	0.503596	0.503596	2.876625	0.765140	3.835316	1.035272	1.035272	9.282276	4.898825	1.284085	13					
49	0.958725	0.257936	0.958725	1.910200	0.503310	0.503310	2.876175	0.764901	3.834712	1.035272	1.035272	9.282276	4.898825	1.284085	12					
50	0.958575	0.257928	0.958575	1.909750	0.503024	0.503024	2.875725	0.764662	3.834108	1.035272	1.035272	9.282276	4.898825	1.284085	11					
51	0.958425	0.257920	0.958425	1.909300	0.502738	0.502738	2.875275	0.764423	3.833504	1.035272	1.035272	9.282276	4.898825	1.284085	10					
52	0.958275	0.257912	0.958275	1.908850	0.502452	0.502452	2.874825	0.764184	3.832900	1.035272	1.035272	9.282276	4.898825	1.284085	9					
53	0.958125	0.257904	0.958125	1.908400	0.502166	0.502166	2.874375	0.763945	3.832296	1.035272	1.035272	9.282276	4.8							

[illegible]



Degrees and Minutes	Measured Distance, or Hypotenuse, 1, 10, 100, 1000, or 100,000.				Measured Distance, or Hypotenuse, 2, 30, 300, 3000, or 300,000.				Measured Distance, or Hypotenuse, 4, 40, 400, 4000, or 400,000.				Measured Distance, or Hypotenuse, 5, 50, 500, 5000, or 500,000.				Degrees and Minutes
	Distance from	Latitude of	Longitude of	Distance to	Distance from	Latitude of	Longitude of	Distance to	Distance from	Latitude of	Longitude of	Distance to	Distance from	Latitude of	Longitude of	Distance to	
18	0.809017	1.902112	0.618034	2.853168	0.927051	3.804024	1.236068	4.755289	3.803504	1.236068	4.755289	3.803504	1.236068	4.755289	3.803504	1.236068	60°
19	0.808776	1.901752	0.618134	2.852928	0.926791	3.803764	1.235828	4.755049	3.803244	1.235828	4.755049	3.803244	1.235828	4.755049	3.803244	1.235828	58
20	0.808535	1.901392	0.618234	2.852688	0.926531	3.803524	1.235588	4.754809	3.803004	1.235588	4.754809	3.803004	1.235588	4.754809	3.803004	1.235588	56
21	0.808294	1.901032	0.618334	2.852448	0.926271	3.803284	1.235348	4.754569	3.802764	1.235348	4.754569	3.802764	1.235348	4.754569	3.802764	1.235348	54
22	0.808053	1.900672	0.618434	2.852208	0.926011	3.803044	1.235108	4.754329	3.802524	1.235108	4.754329	3.802524	1.235108	4.754329	3.802524	1.235108	52
23	0.807812	1.900312	0.618534	2.851968	0.925751	3.802804	1.234868	4.754089	3.802284	1.234868	4.754089	3.802284	1.234868	4.754089	3.802284	1.234868	50
24	0.807571	1.899952	0.618634	2.851728	0.925491	3.802564	1.234628	4.753849	3.802044	1.234628	4.753849	3.802044	1.234628	4.753849	3.802044	1.234628	48
25	0.807330	1.899592	0.618734	2.851488	0.925231	3.802324	1.234388	4.753609	3.801804	1.234388	4.753609	3.801804	1.234388	4.753609	3.801804	1.234388	46
26	0.807089	1.899232	0.618834	2.851248	0.924971	3.802084	1.234148	4.753369	3.801564	1.234148	4.753369	3.801564	1.234148	4.753369	3.801564	1.234148	44
27	0.806848	1.898872	0.618934	2.851008	0.924711	3.801844	1.233908	4.753129	3.801324	1.233908	4.753129	3.801324	1.233908	4.753129	3.801324	1.233908	42
28	0.806607	1.898512	0.619034	2.850768	0.924451	3.801604	1.233668	4.752889	3.801084	1.233668	4.752889	3.801084	1.233668	4.752889	3.801084	1.233668	40
29	0.806366	1.898152	0.619134	2.850528	0.924191	3.801364	1.233428	4.752649	3.800844	1.233428	4.752649	3.800844	1.233428	4.752649	3.800844	1.233428	38
30	0.806125	1.897792	0.619234	2.850288	0.923931	3.801124	1.233188	4.752409	3.800604	1.233188	4.752409	3.800604	1.233188	4.752409	3.800604	1.233188	36
31	0.805884	1.897432	0.619334	2.850048	0.923671	3.800884	1.232948	4.752169	3.800364	1.232948	4.752169	3.800364	1.232948	4.752169	3.800364	1.232948	34
32	0.805643	1.897072	0.619434	2.849808	0.923411	3.800644	1.232708	4.751929	3.800124	1.232708	4.751929	3.800124	1.232708	4.751929	3.800124	1.232708	32
33	0.805402	1.896712	0.619534	2.849568	0.923151	3.800404	1.232468	4.751689	3.799884	1.232468	4.751689	3.799884	1.232468	4.751689	3.799884	1.232468	30
34	0.805161	1.896352	0.619634	2.849328	0.922891	3.800164	1.232228	4.751449	3.799644	1.232228	4.751449	3.799644	1.232228	4.751449	3.799644	1.232228	28
35	0.804920	1.895992	0.619734	2.849088	0.922631	3.799924	1.231988	4.751209	3.799404	1.231988	4.751209	3.799404	1.231988	4.751209	3.799404	1.231988	26
36	0.804679	1.895632	0.619834	2.848848	0.922371	3.799684	1.231748	4.750969	3.799164	1.231748	4.750969	3.799164	1.231748	4.750969	3.799164	1.231748	24
37	0.804438	1.895272	0.619934	2.848608	0.922111	3.799444	1.231508	4.750729	3.798924	1.231508	4.750729	3.798924	1.231508	4.750729	3.798924	1.231508	22
38	0.804197	1.894912	0.620034	2.848368	0.921851	3.799204	1.231268	4.750489	3.798684	1.231268	4.750489	3.798684	1.231268	4.750489	3.798684	1.231268	20
39	0.803956	1.894552	0.620134	2.848128	0.921591	3.798964	1.231028	4.750249	3.798444	1.231028	4.750249	3.798444	1.231028	4.750249	3.798444	1.231028	18
40	0.803715	1.894192	0.620234	2.847888	0.921331	3.798724	1.230788	4.750009	3.798204	1.230788	4.750009	3.798204	1.230788	4.750009	3.798204	1.230788	16
41	0.803474	1.893832	0.620334	2.847648	0.921071	3.798484	1.230548	4.749769	3.797964	1.230548	4.749769	3.797964	1.230548	4.749769	3.797964	1.230548	14
42	0.803233	1.893472	0.620434	2.847408	0.920811	3.798244	1.230308	4.749529	3.797724	1.230308	4.749529	3.797724	1.230308	4.749529	3.797724	1.230308	12
43	0.802992	1.893112	0.620534	2.847168	0.920551	3.798004	1.230068	4.749289	3.797484	1.230068	4.749289	3.797484	1.230068	4.749289	3.797484	1.230068	10
44	0.802751	1.892752	0.620634	2.846928	0.920291	3.797764	1.229828	4.749049	3.797244	1.229828	4.749049	3.797244	1.229828	4.749049	3.797244	1.229828	8
45	0.802510	1.892392	0.620734	2.846688	0.920031	3.797524	1.229588	4.748809	3.797004	1.229588	4.748809	3.797004	1.229588	4.748809	3.797004	1.229588	6
46	0.802269	1.892032	0.620834	2.846448	0.919771	3.797284	1.229348	4.748569	3.796764	1.229348	4.748569	3.796764	1.229348	4.748569	3.796764	1.229348	4
47	0.802028	1.891672	0.620934	2.846208	0.919511	3.797044	1.229108	4.748329	3.796504	1.229108	4.748329	3.796504	1.229108	4.748329	3.796504	1.229108	2
48	0.801787	1.891312	0.621034	2.845968	0.919251	3.796804	1.228868	4.748089	3.796264	1.228868	4.748089	3.796264	1.228868	4.748089	3.796264	1.228868	0
49	0.801546	1.890952	0.621134	2.845728	0.918991	3.796564	1.228628	4.747849	3.796004	1.228628	4.747849	3.796004	1.228628	4.747849	3.796004	1.228628	70°

### TRAVERSE TABLES.

Degrees and Minutes.	Measured Distance, or Hypothesis.			Measured Distance, or Hypothesis.			Measured Distance, or Hypothesis.			Measured Distance, or Hypothesis.			Measured Distance, or Hypothesis.			Measured Distance, or Hypothesis.			Measured Distance, or Hypothesis.		
	Place from North or South.	Place from East or West.	Distance.	Place from North or South.	Place from East or West.	Distance.	Place from North or South.	Place from East or West.	Distance.	Place from North or South.	Place from East or West.	Distance.	Place from North or South.	Place from East or West.	Distance.	Place from North or South.	Place from East or West.	Distance.	Place from North or South.	Place from East or West.	Distance.
19	9.445718	9.325568	1.9810336	0.6511136	0.657732	1.8897562	0.653368	0.657732	1.8897562	0.653368	0.657732	1.8897562	0.653368	0.657732	1.8897562	0.653368	0.657732	1.8897562	0.653368	0.657732	1.8897562
20	9.445718	9.326118	1.9810336	0.6511136	0.657732	1.8897562	0.653368	0.657732	1.8897562	0.653368	0.657732	1.8897562	0.653368	0.657732	1.8897562	0.653368	0.657732	1.8897562	0.653368	0.657732	1.8897562
21	9.445718	9.326668	1.9802738	0.6533336	0.6584434	1.8907896	0.6533336	0.6584434	1.8907896	0.6533336	0.6584434	1.8907896	0.6533336	0.6584434	1.8907896	0.6533336	0.6584434	1.8907896	0.6533336	0.6584434	1.8907896
22	9.445718	9.327217	1.9807896	0.6533336	0.6584434	1.8907896	0.6533336	0.6584434	1.8907896	0.6533336	0.6584434	1.8907896	0.6533336	0.6584434	1.8907896	0.6533336	0.6584434	1.8907896	0.6533336	0.6584434	1.8907896
23	9.445718	9.327767	1.9809516	0.6533336	0.6584434	1.8907896	0.6533336	0.6584434	1.8907896	0.6533336	0.6584434	1.8907896	0.6533336	0.6584434	1.8907896	0.6533336	0.6584434	1.8907896	0.6533336	0.6584434	1.8907896
24	9.445718	9.328317	1.9813134	0.6565634	0.6584434	1.8907896	0.6565634	0.6584434	1.8907896	0.6565634	0.6584434	1.8907896	0.6565634	0.6584434	1.8907896	0.6565634	0.6584434	1.8907896	0.6565634	0.6584434	1.8907896
25	9.445718	9.328866	1.9817562	0.657732	0.6584434	1.8907896	0.657732	0.6584434	1.8907896	0.657732	0.6584434	1.8907896	0.657732	0.6584434	1.8907896	0.657732	0.6584434	1.8907896	0.657732	0.6584434	1.8907896
26	9.445718	9.329416	1.9821990	0.6584434	0.6584434	1.8907896	0.6584434	0.6584434	1.8907896	0.6584434	0.6584434	1.8907896	0.6584434	0.6584434	1.8907896	0.6584434	0.6584434	1.8907896	0.6584434	0.6584434	1.8907896
27	9.445718	9.329965	1.9826418	0.6596128	0.6584434	1.8907896	0.6596128	0.6584434	1.8907896	0.6596128	0.6584434	1.8907896	0.6596128	0.6584434	1.8907896	0.6596128	0.6584434	1.8907896	0.6596128	0.6584434	1.8907896
28	9.445718	9.330514	1.9830846	0.6601228	0.6584434	1.8907896	0.6601228	0.6584434	1.8907896	0.6601228	0.6584434	1.8907896	0.6601228	0.6584434	1.8907896	0.6601228	0.6584434	1.8907896	0.6601228	0.6584434	1.8907896
29	9.445718	9.331063	1.9835274	0.661228	0.6584434	1.8907896	0.661228	0.6584434	1.8907896	0.661228	0.6584434	1.8907896	0.661228	0.6584434	1.8907896	0.661228	0.6584434	1.8907896	0.661228	0.6584434	1.8907896
30	9.445718	9.331612	1.9839702	0.662328	0.6584434	1.8907896	0.662328	0.6584434	1.8907896	0.662328	0.6584434	1.8907896	0.662328	0.6584434	1.8907896	0.662328	0.6584434	1.8907896	0.662328	0.6584434	1.8907896
31	9.445718	9.332161	1.9844130	0.663428	0.6584434	1.8907896	0.663428	0.6584434	1.8907896	0.663428	0.6584434	1.8907896	0.663428	0.6584434	1.8907896	0.663428	0.6584434	1.8907896	0.663428	0.6584434	1.8907896
32	9.445718	9.332711	1.9848558	0.664528	0.6584434	1.8907896	0.664528	0.6584434	1.8907896	0.664528	0.6584434	1.8907896	0.664528	0.6584434	1.8907896	0.664528	0.6584434	1.8907896	0.664528	0.6584434	1.8907896
33	9.445718	9.333260	1.9852986	0.665628	0.6584434	1.8907896	0.665628	0.6584434	1.8907896	0.665628	0.6584434	1.8907896	0.665628	0.6584434	1.8907896	0.665628	0.6584434	1.8907896	0.665628	0.6584434	1.8907896
34	9.445718	9.333810	1.9857414	0.666728	0.6584434	1.8907896	0.666728	0.6584434	1.8907896	0.666728	0.6584434	1.8907896	0.666728	0.6584434	1.8907896	0.666728	0.6584434	1.8907896	0.666728	0.6584434	1.8907896
35	9.445718	9.334359	1.9861842	0.667828	0.6584434	1.8907896	0.667828	0.6584434	1.8907896	0.667828	0.6584434	1.8907896	0.667828	0.6584434	1.8907896	0.667828	0.6584434	1.8907896	0.667828	0.6584434	1.8907896
36	9.445718	9.334908	1.9866270	0.668928	0.6584434	1.8907896	0.668928	0.6584434	1.8907896	0.668928	0.6584434	1.8907896	0.668928	0.6584434	1.8907896	0.668928	0.6584434	1.8907896	0.668928	0.6584434	1.8907896
37	9.445718	9.335457	1.9870698	0.670028	0.6584434	1.8907896	0.670028	0.6584434	1.8907896	0.670028	0.6584434	1.8907896	0.670028	0.6584434	1.8907896	0.670028	0.6584434	1.8907896	0.670028	0.6584434	1.8907896
38	9.445718	9.336006	1.9875126	0.671128	0.6584434	1.8907896	0.671128	0.6584434	1.8907896	0.671128	0.6584434	1.8907896	0.671128	0.6584434	1.8907896	0.671128	0.6584434	1.8907896	0.671128	0.6584434	1.8907896
39	9.445718	9.336554	1.9879554	0.672228	0.6584434	1.8907896	0.672228	0.6584434	1.8907896	0.672228	0.6584434	1.8907896	0.672228	0.6584434	1.8907896	0.672228	0.6584434	1.8907896	0.672228	0.6584434	1.8907896
40	9.445718	9.337103	1.9883982	0.673328	0.6584434	1.8907896	0.673328	0.6584434	1.8907896	0.673328	0.6584434	1.8907896	0.673328	0.6584434	1.8907896	0.673328	0.6584434	1.8907896	0.673328	0.6584434	1.8907896
41	9.445718	9.337652	1.9888410	0.674428	0.6584434	1.8907896	0.674428	0.6584434	1.8907896	0.674428	0.6584434	1.8907896	0.674428	0.6584434	1.8907896	0.674428	0.6584434	1.8907896	0.674428	0.6584434	1.8907896
42	9.445718	9.338201	1.9892838	0.675528	0.6584434	1.8907896	0.675528	0.6584434	1.8907896	0.675528	0.6584434	1.8907896	0.675528	0.6584434	1.8907896	0.675528	0.6584434	1.8907896	0.675528	0.6584434	1.8907896
43	9.445718	9.338750	1.9897266	0.676628	0.6584434	1.8907896	0.676628	0.6584434	1.8907896	0.676628	0.6584434	1.8907896	0.676628	0.6584434	1.8907896	0.676628	0.6584434	1.8907896	0.676628	0.6584434	1.8907896
44	9.445718	9.339300	1.9901694	0.677728	0.6584434	1.8907896	0.677728	0.6584434	1.8907896	0.677728	0.6584434	1.8907896	0.677728	0.6584434	1.8907896	0.677728	0.6584434	1.8907896	0.677728	0.6584434	1.8907896
45	9.445718	9.339849	1.9906122	0.678828	0.6584434	1.8907896	0.678828	0.6584434	1.8907896	0.678828	0.6584434	1.8907896	0.678828	0.6584434	1.8907896	0.678828	0.6584434	1.8907896	0.678828	0.6584434	1.8907896
46	9.445718	9.340398	1.9910550	0.679928	0.6584434	1.8907896	0.679928	0.6584434	1.8907896	0.679928	0.6584434	1.8907896	0.679928	0.6584434	1.8907896	0.679928	0.6584434	1.8907896	0.679928	0.6584434	1.8907896
47	9.445718	9.340947	1.9914978	0.681028	0.6584434	1.8907896	0.681028	0.6584434	1.8907896	0.681028	0.6584434	1.8907896	0.681028	0.6584434	1.8907896	0.681028	0.6584434	1.8907896	0.681028	0.6584434	1.8907896
48	9.445718	9.341496	1.9919406	0.682128	0.6584434	1.8907896	0.682128	0.6584434	1.8907896	0.682128	0.6584434	1.8907896	0.682128	0.6584434	1.8907896	0.682128	0.6584434	1.8907896	0.682128	0.6584434	1.8907896
49	9.445718	9.342045	1.9923834	0.683228	0.6584434	1.8907896	0.683228	0.6584434	1.8907896	0.683228	0.6584434	1.8907896	0.683228	0.6584434	1.8907896	0.683228	0.6584434	1.8907896	0.683228	0.6584434	1.8907896
50	9.445718	9.342594	1.9928262	0.684328	0.6584434	1.8907896	0.684328	0.6584434	1.8907896	0.684328	0.6584434	1.8907896	0.684328	0.6584434	1.8907896	0.684328	0.6584434	1.8907896	0.684328	0.6584434	1.8907896
51	9.445718	9.343143	1.9932690	0.685428	0.6584434	1.8907896	0.685428	0.6584434	1.8907896	0.685428	0.6584434	1.8907896	0.685428	0.6584434	1.8907896	0.685428	0.6584434	1.8907896	0.685428	0.6584434	1.8907896
52	9.445718	9.343692	1.9937118	0.686528	0.6584434	1.8907896	0.686528	0.6584434	1.8907896	0.686528	0.6584434	1.8907896	0.686528	0.6584434	1.8907896	0.686528	0.6584434	1.8907896	0.686528	0.6584434	1.8907896
53	9.445718	9.344241	1.9941546	0.687628	0.6584434	1.8907896	0.687628	0.6584434	1.8907896	0.687628	0.6584434	1.8907896	0.687628	0.6584434	1.8907896	0.687628	0.6584434	1.8907896	0.687628	0.6584434	1.8907896
54	9.445718	9.344790	1.9945974	0.688728	0.6584434	1.8907896	0.688728	0.6584434	1.8907896	0.688728	0.6584434	1.8907896	0.688728	0.6584434	1.8907896	0.688728	0.6584434	1.8907896	0.688728	0.6584434	1.8907896
55	9.445718	9.345339	1.9950402	0.689828	0.6584434	1.8907896	0.689828	0.6584434	1.8907896	0.689828	0.6584434	1.8907896	0.689828	0.6584434	1.8907896	0.689828	0.6584434	1.8907896	0.689828	0.6584434	1.8907896
56	9.445718	9.345888	1.9954830	0.690928	0.6584434	1.8907896	0.690928	0.6584434	1.8907896	0.690928	0.6584434	1.8907896	0.690928	0.6584434	1.8907896	0.690928	0.6584434	1.8907896	0.690928	0.6584434	1.8907896
57	9.445718	9.346437	1.9959258	0.692028	0.6584434	1.8907896	0.692028	0.6584434	1.8907896	0.692028	0.6584434	1.8907896	0.692028	0.6584434	1.8907896	0.692028	0.6584434	1.8907896	0.692028	0.6584434	1.8907896
58	9.445718	9.346986	1.9963686	0.693128	0.6584434	1.8907896	0.693128	0.6584434	1.8907896	0.693128	0.6584434	1.8907896	0.693128	0.6584434	1.8907896	0.693128	0.6584434	1.8907896	0.693128	0.6584434	1.8907896
59	9.445718	9.347535	1.9968114	0.694228	0.6584434	1.8907896	0.694228	0.6584434	1.8907896	0.694228	0.6584434	1.89									





Degrees and Minutes.	Measured Distance, or Hypothesis, 1, 10, 100, 1,000, or 100,000.				Measured Distance, or Hypothesis, 2, 20, 200, 2,000, or 200,000.				Measured Distance, or Hypothesis, 3, 30, 300, 3,000, or 300,000.				Measured Distance, or Hypothesis, 4, 40, 400, 4,000, or 400,000.				Measured Distance, or Hypothesis, 5, 50, 500, 5,000, or 500,000.				Degrees and Minutes.
	Distance from Place of East or West.	Latitude of Place of East or West.	Distance from Place of East or West.	Distance from Place of East or West.	Distance from Place of East or West.	Latitude of Place of East or West.	Distance from Place of East or West.	Distance from Place of East or West.	Distance from Place of East or West.	Latitude of Place of East or West.	Distance from Place of East or West.	Distance from Place of East or West.	Distance from Place of East or West.	Latitude of Place of East or West.	Distance from Place of East or West.	Distance from Place of East or West.	Distance from Place of East or West.	Latitude of Place of East or West.	Distance from Place of East or West.	Distance from Place of East or West.	
57	0.927300	4.635915	1.493424	3.703732	1.123818	2.781549	2.781549	1.123818	3.703732	1.123818	2.781549	2.781549	1.123818	3.703732	1.123818	2.781549	2.781549	1.123818	3.703732	1.123818	57
58	1.875725	4.634826	1.500580	3.707380	1.125435	2.780895	2.780895	1.125435	3.707380	1.125435	2.780895	2.780895	1.125435	3.707380	1.125435	2.780895	2.780895	1.125435	3.707380	1.125435	58
59	1.873425	4.633735	1.502740	3.706988	1.127055	2.780241	2.780241	1.127055	3.706988	1.127055	2.780241	2.780241	1.127055	3.706988	1.127055	2.780241	2.780241	1.127055	3.706988	1.127055	59
60	1.871120	4.632640	1.504806	3.706112	1.128672	2.779584	2.779584	1.128672	3.706112	1.128672	2.779584	2.779584	1.128672	3.706112	1.128672	2.779584	2.779584	1.128672	3.706112	1.128672	60
51	1.868815	4.631545	1.506872	3.705236	1.130289	2.778927	2.778927	1.130289	3.705236	1.130289	2.778927	2.778927	1.130289	3.705236	1.130289	2.778927	2.778927	1.130289	3.705236	1.130289	51
52	1.866510	4.630450	1.508938	3.704360	1.131906	2.778270	2.778270	1.131906	3.704360	1.131906	2.778270	2.778270	1.131906	3.704360	1.131906	2.778270	2.778270	1.131906	3.704360	1.131906	52
53	1.864205	4.629355	1.511004	3.703484	1.133523	2.777613	2.777613	1.133523	3.703484	1.133523	2.777613	2.777613	1.133523	3.703484	1.133523	2.777613	2.777613	1.133523	3.703484	1.133523	53
54	1.861900	4.628260	1.513070	3.702608	1.135140	2.776956	2.776956	1.135140	3.702608	1.135140	2.776956	2.776956	1.135140	3.702608	1.135140	2.776956	2.776956	1.135140	3.702608	1.135140	54
55	1.859595	4.627165	1.515136	3.701732	1.136757	2.776300	2.776300	1.136757	3.701732	1.136757	2.776300	2.776300	1.136757	3.701732	1.136757	2.776300	2.776300	1.136757	3.701732	1.136757	55
56	1.857290	4.626070	1.517202	3.700856	1.138374	2.775643	2.775643	1.138374	3.700856	1.138374	2.775643	2.775643	1.138374	3.700856	1.138374	2.775643	2.775643	1.138374	3.700856	1.138374	56
57	1.854985	4.624975	1.519268	3.699980	1.139991	2.774986	2.774986	1.139991	3.699980	1.139991	2.774986	2.774986	1.139991	3.699980	1.139991	2.774986	2.774986	1.139991	3.699980	1.139991	57
58	1.852680	4.623880	1.521334	3.699104	1.141608	2.774330	2.774330	1.141608	3.699104	1.141608	2.774330	2.774330	1.141608	3.699104	1.141608	2.774330	2.774330	1.141608	3.699104	1.141608	58
59	1.850375	4.622785	1.523400	3.698228	1.143225	2.773673	2.773673	1.143225	3.698228	1.143225	2.773673	2.773673	1.143225	3.698228	1.143225	2.773673	2.773673	1.143225	3.698228	1.143225	59
60	1.848070	4.621690	1.525466	3.697352	1.144842	2.773016	2.773016	1.144842	3.697352	1.144842	2.773016	2.773016	1.144842	3.697352	1.144842	2.773016	2.773016	1.144842	3.697352	1.144842	60
61	1.845765	4.620595	1.527532	3.696476	1.146459	2.772360	2.772360	1.146459	3.696476	1.146459	2.772360	2.772360	1.146459	3.696476	1.146459	2.772360	2.772360	1.146459	3.696476	1.146459	61
62	1.843460	4.619500	1.529598	3.695600	1.148076	2.771703	2.771703	1.148076	3.695600	1.148076	2.771703	2.771703	1.148076	3.695600	1.148076	2.771703	2.771703	1.148076	3.695600	1.148076	62
63	1.841155	4.618405	1.531664	3.694724	1.149693	2.771046	2.771046	1.149693	3.694724	1.149693	2.771046	2.771046	1.149693	3.694724	1.149693	2.771046	2.771046	1.149693	3.694724	1.149693	63
64	1.838850	4.617310	1.533730	3.693848	1.151310	2.770390	2.770390	1.151310	3.693848	1.151310	2.770390	2.770390	1.151310	3.693848	1.151310	2.770390	2.770390	1.151310	3.693848	1.151310	64
65	1.836545	4.616215	1.535796	3.692972	1.152927	2.769733	2.769733	1.152927	3.692972	1.152927	2.769733	2.769733	1.152927	3.692972	1.152927	2.769733	2.769733	1.152927	3.692972	1.152927	65
66	1.834240	4.615120	1.537862	3.692096	1.154544	2.769076	2.769076	1.154544	3.692096	1.154544	2.769076	2.769076	1.154544	3.692096	1.154544	2.769076	2.769076	1.154544	3.692096	1.154544	66
67	1.831935	4.614025	1.539928	3.691220	1.156161	2.768420	2.768420	1.156161	3.691220	1.156161	2.768420	2.768420	1.156161	3.691220	1.156161	2.768420	2.768420	1.156161	3.691220	1.156161	67
68	1.829630	4.612930	1.541994	3.690344	1.157778	2.767763	2.767763	1.157778	3.690344	1.157778	2.767763	2.767763	1.157778	3.690344	1.157778	2.767763	2.767763	1.157778	3.690344	1.157778	68
69	1.827325	4.611835	1.544060	3.689468	1.159395	2.767106	2.767106	1.159395	3.689468	1.159395	2.767106	2.767106	1.159395	3.689468	1.159395	2.767106	2.767106	1.159395	3.689468	1.159395	69
70	1.825020	4.610740	1.546126	3.688592	1.161012	2.766450	2.766450	1.161012	3.688592	1.161012	2.766450	2.766450	1.161012	3.688592	1.161012	2.766450	2.766450	1.161012	3.688592	1.161012	70
71	1.822715	4.609645	1.548192	3.687716	1.162629	2.765793	2.765793	1.162629	3.687716	1.162629	2.765793	2.765793	1.162629	3.687716	1.162629	2.765793	2.765793	1.162629	3.687716	1.162629	71
72	1.820410	4.608550	1.550258	3.686840	1.164246	2.765136	2.765136	1.164246	3.686840	1.164246	2.765136	2.765136	1.164246	3.686840	1.164246	2.765136	2.765136	1.164246	3.686840	1.164246	72
73	1.818105	4.607455	1.552324	3.685964	1.165863	2.764479	2.764479	1.165863	3.685964	1.165863	2.764479	2.764479	1.165863	3.685964	1.165863	2.764479	2.764479	1.165863	3.685964	1.165863	73
74	1.815800	4.606360	1.554390	3.685088	1.167480	2.763822	2.763822	1.167480	3.685088	1.167480	2.763822	2.763822	1.167480	3.685088	1.167480	2.763822	2.763822	1.167480	3.685088	1.167480	74
75	1.813495	4.605265	1.556456	3.684212	1.169097	2.763165	2.763165	1.169097	3.684212	1.169097	2.763165	2.763165	1.169097	3.684212	1.169097	2.763165	2.763165	1.169097	3.684212	1.169097	75
76	1.811190	4.604170	1.558522	3.683336	1.170714	2.762508	2.762508	1.170714	3.683336	1.170714	2.762508	2.762508	1.170714	3.683336	1.170714	2.762508	2.762508	1.170714	3.683336	1.170714	76
77	1.808885	4.603075	1.560588	3.682460	1.172331	2.761851	2.761851	1.172331	3.682460	1.172331	2.761851	2.761851	1.172331	3.682460	1.172331	2.761851	2.761851	1.172331	3.682460	1.172331	77
78	1.806580	4.601980	1.562654	3.681584	1.173948	2.761194	2.761194	1.173948	3.681584	1.173948	2.761194	2.761194	1.173948	3.681584	1.173948	2.761194	2.761194	1.173948	3.681584	1.173948	78
79	1.804275	4.600885	1.564720	3.680708	1.175565	2.760537	2.760537	1.175565	3.680708	1.175565	2.760537	2.760537	1.175565	3.680708	1.175565	2.760537	2.760537	1.175565	3.680708	1.175565	79
80	1.801970	4.600000	1.566786	3.679832	1.177182	2.759880	2.759880	1.177182	3.679832	1.177182	2.759880	2.759880	1.177182	3.679832	1.177182	2.759880	2.759880	1.177182	3.679832	1.177182	80
81	1.800000	4.600000	1.568852	3.678956	1.178799	2.759223	2.759223	1.178799	3.678956	1.178799	2.759223	2.759223	1.178799	3.678956	1.178799	2.759223	2.759223	1.178799	3.678956	1.178799	81
82	1.798030	4.600000	1.570918	3.678080	1.180416	2.758566	2.758566	1.180416	3.678080	1.180416	2.758566	2.758566	1.180416	3.678080	1.180416	2.758566	2.758566	1.180416	3.678080	1.180416	82
83	1.796060	4.600000	1.572984	3.677204	1.182033	2.757909	2.757909	1.182033	3.677204	1.182033	2.757909	2.757909	1.182033	3.677204	1.182033	2.757909	2.757909	1.182033	3.677204	1.182033	83
84	1.794090	4.600000	1.575050	3.676328	1.183650	2.757252	2.757252	1.183650	3.676328	1.183650	2.757252	2.757252	1.183650	3.676328	1.183650	2.757252	2.757252	1.183650	3.676328	1.183650	84
85	1.792120	4.600000	1.577116	3.675452	1.185267	2.756595	2.756595	1.185267	3.675452	1.185267	2.756595	2.756595	1.185267	3.675452	1.185267	2.756595	2.756595	1.185267	3.675452	1.185267	85
86	1.790150	4.600000	1.579182	3.674576	1.186884	2.755938	2.755938	1.186884	3.674576	1.186884	2.755938	2.755938	1.186884	3.674576	1.186884	2.755938	2.755938	1.186884	3.674576	1.186884	86
87	1.788180	4.600000	1.581248	3.673700	1.188501	2.755281	2.755281	1.188501	3.673700	1.188501	2.755281	2.755281	1.188501	3.673700	1.188501	2.755281	2.755281	1.188501	3.673700	1.188501	87
88	1.786210	4.600000	1.583314	3.672824	1.190118	2.754624	2.754624	1.190118	3.672824	1.190118	2.754624	2.754624	1.								



### TRAVERSE TABLES.

Degrees and Minutes	Measured Distance, or Hypothenuse, of 1, 10, 100, 1,000, or 100,000			Measured Distance, or Hypothenuse, of 3, 30, 300, 3,000, or 300,000			Measured Distance, or Hypothenuse, of 4, 40, 400, 4,000, or 400,000			Measured Distance, or Hypothenuse, of 5, 50, 500, 5,000, or 500,000		
	Distance from East or West	Distance from North or South	Distance from East or West	Distance from North or South	Distance from East or West	Distance from North or South	Distance from East or West	Distance from North or South	Distance from East or West	Distance from North or South	Distance from East or West	Distance from North or South
23	0.9208564	0.3907331	1.841008	2.761312	1.172193	3.682016	1.562924	4.002320	1.958555	4.602320	1.958555	60
24	0.9202774	0.3912666	1.841058	2.762532	1.172532	3.683108	1.565064	4.001385	1.956330	4.595330	1.956330	58
25	0.9196984	0.3918001	1.841108	2.763652	1.172872	3.684200	1.567204	4.000450	1.954105	4.594105	1.954105	56
26	0.9191194	0.3923336	1.841158	2.764772	1.173212	3.685292	1.569344	4.589416	1.951880	4.589416	1.951880	54
27	0.9185404	0.3928671	1.841208	2.765892	1.173552	3.686384	1.571484	4.588481	1.949655	4.588481	1.949655	52
28	0.9179614	0.3934006	1.841258	2.767012	1.173892	3.687476	1.573624	4.587546	1.947430	4.587546	1.947430	50
29	0.9173824	0.3939341	1.841308	2.768132	1.174232	3.688568	1.575764	4.586611	1.945205	4.586611	1.945205	48
30	0.9168034	0.3944676	1.841358	2.769252	1.174572	3.689660	1.577904	4.585676	1.942980	4.585676	1.942980	46
31	0.9162244	0.3950011	1.841408	2.770372	1.174912	3.690752	1.580044	4.584741	1.940755	4.584741	1.940755	44
32	0.9156454	0.3955346	1.841458	2.771492	1.175252	3.691844	1.582184	4.583806	1.938530	4.583806	1.938530	42
33	0.9150664	0.3960681	1.841508	2.772612	1.175592	3.692936	1.584324	4.582871	1.936305	4.582871	1.936305	40
34	0.9144874	0.3966016	1.841558	2.773732	1.175932	3.694028	1.586464	4.581936	1.934080	4.581936	1.934080	38
35	0.9139084	0.3971351	1.841608	2.774852	1.176272	3.695120	1.588604	4.581001	1.931855	4.581001	1.931855	36
36	0.9133294	0.3976686	1.841658	2.775972	1.176612	3.696212	1.590744	4.580066	1.929630	4.580066	1.929630	34
37	0.9127504	0.3982021	1.841708	2.777092	1.176952	3.697304	1.592884	4.579131	1.927405	4.579131	1.927405	32
38	0.9121714	0.3987356	1.841758	2.778212	1.177292	3.698396	1.595024	4.578196	1.925180	4.578196	1.925180	30
39	0.9115924	0.3992691	1.841808	2.779332	1.177632	3.699488	1.597164	4.577261	1.922955	4.577261	1.922955	28
40	0.9110134	0.3998026	1.841858	2.780452	1.177972	3.700580	1.599304	4.576326	1.920730	4.576326	1.920730	26
41	0.9104344	0.4003361	1.841908	2.781572	1.178312	3.701672	1.601444	4.575391	1.918505	4.575391	1.918505	24
42	0.9098554	0.4008696	1.841958	2.782692	1.178652	3.702764	1.603584	4.574456	1.916280	4.574456	1.916280	22
43	0.9092764	0.4014031	1.842008	2.783812	1.178992	3.703856	1.605724	4.573521	1.914055	4.573521	1.914055	20
44	0.9086974	0.4019366	1.842058	2.784932	1.179332	3.704948	1.607864	4.572586	1.911830	4.572586	1.911830	18
45	0.9081184	0.4024701	1.842108	2.786052	1.179672	3.706040	1.610004	4.571651	1.909605	4.571651	1.909605	16
46	0.9075394	0.4030036	1.842158	2.787172	1.179992	3.707132	1.612144	4.570716	1.907380	4.570716	1.907380	14
47	0.9069604	0.4035371	1.842208	2.788292	1.180312	3.708224	1.614288	4.569781	1.905155	4.569781	1.905155	12
48	0.9063814	0.4040706	1.842258	2.789412	1.180632	3.709316	1.616432	4.568846	1.902930	4.568846	1.902930	10
49	0.9058024	0.4046041	1.842308	2.790532	1.180952	3.710408	1.618576	4.567911	1.900705	4.567911	1.900705	8
50	0.9052234	0.4051376	1.842358	2.791652	1.181272	3.711500	1.620720	4.566976	1.898480	4.566976	1.898480	6
51	0.9046444	0.4056711	1.842408	2.792772	1.181592	3.712592	1.622864	4.566041	1.896255	4.566041	1.896255	4
52	0.9040654	0.4062046	1.842458	2.793892	1.181912	3.713684	1.625008	4.565106	1.894030	4.565106	1.894030	2
53	0.9034864	0.4067381	1.842508	2.795012	1.182232	3.714776	1.627152	4.564171	1.891805	4.564171	1.891805	0
54	0.9029074	0.4072716	1.842558	2.796132	1.182552	3.715868	1.629296	4.563236	1.889580	4.563236	1.889580	60

Degrees and Minutes.	Measured Distances, or Hypotheses, 1, 10, 100, 1000, 10,000, or 100,000.				Measured Distances, or Hypotheses, 2, 20, 200, 2000, 20,000, or 200,000.				Measured Distances, or Hypotheses, 3, 30, 300, 3000, or 300,000.				Measured Distances, or Hypotheses, 4, 40, 400, 4000, or 400,000.				Measured Distances, or Hypotheses, 5, 50, 500, 5000, or 500,000.				Degrees and Minutes.
	Distance from Meridian, or East or West.	Latitude, or North or South.	Distance from Meridian, or East or West.	Distance from Meridian, or East or West.	Distance from Meridian, or East or West.	Latitude, or North or South.	Distance from Meridian, or East or West.	Distance from Meridian, or East or West.	Distance from Meridian, or East or West.	Latitude, or North or South.	Distance from Meridian, or East or West.	Distance from Meridian, or East or West.	Distance from Meridian, or East or West.	Latitude, or North or South.	Distance from Meridian, or East or West.	Distance from Meridian, or East or West.	Distance from Meridian, or East or West.	Latitude, or North or South.	Distance from Meridian, or East or West.	Distance from Meridian, or East or West.	
1	0.913545	0.407265	1.827090	0.814536	2.739342	2.70635	1.220208	3.654180	1.626944	4.567725	2.033680	607									
2	0.913508	0.407285	1.826916	0.814536	2.739342	2.70635	1.220208	3.654180	1.626944	4.567725	2.033680	608									
3	0.913471	0.407305	1.826742	0.814536	2.739342	2.70635	1.220208	3.654180	1.626944	4.567725	2.033680	609									
4	0.913434	0.407325	1.826568	0.814536	2.739342	2.70635	1.220208	3.654180	1.626944	4.567725	2.033680	610									
5	0.913397	0.407345	1.826394	0.814536	2.739342	2.70635	1.220208	3.654180	1.626944	4.567725	2.033680	611									
6	0.913360	0.407365	1.826220	0.814536	2.739342	2.70635	1.220208	3.654180	1.626944	4.567725	2.033680	612									
7	0.913323	0.407385	1.826046	0.814536	2.739342	2.70635	1.220208	3.654180	1.626944	4.567725	2.033680	613									
8	0.913286	0.407405	1.825872	0.814536	2.739342	2.70635	1.220208	3.654180	1.626944	4.567725	2.033680	614									
9	0.913249	0.407425	1.825698	0.814536	2.739342	2.70635	1.220208	3.654180	1.626944	4.567725	2.033680	615									
10	0.913212	0.407445	1.825524	0.814536	2.739342	2.70635	1.220208	3.654180	1.626944	4.567725	2.033680	616									
11	0.913175	0.407465	1.825350	0.814536	2.739342	2.70635	1.220208	3.654180	1.626944	4.567725	2.033680	617									
12	0.913138	0.407485	1.825176	0.814536	2.739342	2.70635	1.220208	3.654180	1.626944	4.567725	2.033680	618									
13	0.913101	0.407505	1.825002	0.814536	2.739342	2.70635	1.220208	3.654180	1.626944	4.567725	2.033680	619									
14	0.913064	0.407525	1.824828	0.814536	2.739342	2.70635	1.220208	3.654180	1.626944	4.567725	2.033680	620									
15	0.913027	0.407545	1.824654	0.814536	2.739342	2.70635	1.220208	3.654180	1.626944	4.567725	2.033680	621									
16	0.912990	0.407565	1.824480	0.814536	2.739342	2.70635	1.220208	3.654180	1.626944	4.567725	2.033680	622									
17	0.912953	0.407585	1.824306	0.814536	2.739342	2.70635	1.220208	3.654180	1.626944	4.567725	2.033680	623									
18	0.912916	0.407605	1.824132	0.814536	2.739342	2.70635	1.220208	3.654180	1.626944	4.567725	2.033680	624									
19	0.912879	0.407625	1.823958	0.814536	2.739342	2.70635	1.220208	3.654180	1.626944	4.567725	2.033680	625									
20	0.912842	0.407645	1.823784	0.814536	2.739342	2.70635	1.220208	3.654180	1.626944	4.567725	2.033680	626									
21	0.912805	0.407665	1.823610	0.814536	2.739342	2.70635	1.220208	3.654180	1.626944	4.567725	2.033680	627									
22	0.912768	0.407685	1.823436	0.814536	2.739342	2.70635	1.220208	3.654180	1.626944	4.567725	2.033680	628									
23	0.912731	0.407705	1.823262	0.814536	2.739342	2.70635	1.220208	3.654180	1.626944	4.567725	2.033680	629									
24	0.912694	0.407725	1.823088	0.814536	2.739342	2.70635	1.220208	3.654180	1.626944	4.567725	2.033680	630									
25	0.912657	0.407745	1.822914	0.814536	2.739342	2.70635	1.220208	3.654180	1.626944	4.567725	2.033680	631									
26	0.912620	0.407765	1.822740	0.814536	2.739342	2.70635	1.220208	3.654180	1.626944	4.567725	2.033680	632									
27	0.912583	0.407785	1.822566	0.814536	2.739342	2.70635	1.220208	3.654180	1.626944	4.567725	2.033680	633									
28	0.912546	0.407805	1.822392	0.814536	2.739342	2.70635	1.220208	3.654180	1.626944	4.567725	2.033680	634									
29	0.912509	0.407825	1.822218	0.814536	2.739342	2.70635	1.220208	3.654180	1.626944	4.567725	2.033680	635									
30	0.912472	0.407845	1.822044	0.814536	2.739342	2.70635	1.220208	3.654180	1.626944	4.567725	2.033680	636									
31	0.912435	0.407865	1.821870	0.814536	2.739342	2.70635	1.220208	3.654180	1.626944	4.567725	2.033680	637									
32	0.912398	0.407885	1.821696	0.814536	2.739342	2.70635	1.220208	3.654180	1.626944	4.567725	2.033680	638									
33	0.912361	0.407905	1.821522	0.814536	2.739342	2.70635	1.220208	3.654180	1.626944	4.567725	2.033680	639									
34	0.912324	0.407925	1.821348	0.814536	2.739342	2.70635	1.220208	3.654180	1.626944	4.567725	2.033680	640									
35	0.912287	0.407945	1.821174	0.814536	2.739342	2.70635	1.220208	3.654180	1.626944	4.567725	2.033680	641									
36	0.912250	0.407965	1.821000	0.814536	2.739342	2.70635	1.220208	3.654180	1.626944	4.567725	2.033680	642									
37	0.912213	0.407985	1.820826	0.814536	2.739342	2.70635	1.220208	3.654180	1.626944	4.567725	2.033680	643									
38	0.912176	0.408005	1.820652	0.814536	2.739342	2.70635	1.220208	3.654180	1.626944	4.567725	2.033680	644									
39	0.912139	0.408025	1.820478	0.814536	2.739342	2.70635	1.220208	3.654180	1.626944	4.567725	2.033680	645									
40	0.912102	0.408045	1.820304	0.814536	2.739342	2.70635	1.220208	3.654180	1.626944	4.567725	2.033680	646									
41	0.912065	0.408065	1.820130	0.814536	2.739342	2.70635	1.220208	3.654180	1.626944	4.567725	2.033680	647									
42	0.912028	0.408085	1.819956	0.814536	2.739342	2.70635	1.220208	3.654180	1.626944	4.567725	2.033680	648									
43	0.911991	0.408105	1.819782	0.814536	2.739342	2.70635	1.220208	3.654180	1.626944	4.567725	2.033680	649									
44	0.911954	0.408125	1.819608	0.814536	2.739342	2.70635	1.220208	3.654180	1.626944	4.567725	2.033680	650									
45	0.911917	0.408145	1.819434	0.814536	2.739342	2.70635	1.220208	3.654180	1.626944	4.567725	2.033680	651									
46	0.911880	0.408165	1.819260	0.814536	2.739342	2.70635	1.220208	3.654180	1.626944	4.567725	2.033680	652									
47	0.911843	0.408185	1.819086	0.814536	2.739342	2.70635	1.220208	3.654180	1.626944	4.567725	2.033680	653									
48	0.911806	0.408205	1.818912	0.814536	2.739342	2.70635	1.220208	3.654180	1.626944	4.567725	2.033680	654									
49	0.911769	0.408225	1.818738	0.814536	2.739342	2.70635	1.220208	3.654180	1.626944	4.567725	2.033680	655									
50	0.911732	0.408245	1.818564	0.814536	2.739342	2.70635	1.220208	3.654180	1.626944	4.567725	2.033680	656									
51	0.911695	0.408265	1.818390	0.814536	2.739342	2.70635	1.220208	3.654180	1.626944	4.567725	2.033680	657									
52	0.911658	0.408285	1.818216	0.814536	2.739342	2.70635	1.220208	3.654180	1.626944	4.567725	2.033680	658									
53	0.911621	0.408305	1.818042	0.814536	2.739342	2.70635	1.220208	3.654180	1.626944	4.567725	2.033680	659									
54	0.911584	0.408325	1.817868	0.814536	2.739342	2.70635	1.220208	3.654180	1.626944	4.567725	2.033680	660									
55	0.911547	0.408345	1.817694	0.814536	2.739342	2.70635	1.220208	3.654180	1.626944	4.567725	2.033680	661									
56	0.911510	0.408365	1.817520	0.814536	2.739342	2.70635	1.220208	3.654180	1.626944	4.567725	2.033680	662									
57	0.911473	0.408385	1.817346	0.814536	2.739342	2.70635	1.220208	3.654180	1.626944	4.567725	2.033680	663									
58	0.911436	0.408405	1.817172	0.814536	2.739342	2.70635	1.220208	3.654180	1.626944	4.567725	2.033680	664									
59	0.911399	0.408425	1.816998	0.814536	2.739342	2.70635	1.22														

Degrees and Minutes	Measured Distance, or Hypothenuse, 1, 10, 100, 1000, 10,000, or 100,000.				Measured Distance, or Hypothenuse, 2, 20, 200, 2000, 20,000, or 200,000.				Measured Distance, or Hypothenuse, 3, 30, 300, 3000, 30,000, or 300,000.				Measured Distance, or Hypothenuse, 4, 40, 400, 4000, 40,000, or 400,000.				Measured Distance, or Hypothenuse, 5, 50, 500, 5000, 50,000, or 500,000.				Degrees and Minutes
	Distance from Plane of Meridian, or East or West.	Latitude of Plane of Meridian, or East or West.	Distance from Plane of Meridian, or East or West.	Distance from Plane of Meridian, or East or West.	Distance from Plane of Meridian, or East or West.	Latitude of Plane of Meridian, or East or West.	Distance from Plane of Meridian, or East or West.	Distance from Plane of Meridian, or East or West.	Distance from Plane of Meridian, or East or West.	Latitude of Plane of Meridian, or East or West.	Distance from Plane of Meridian, or East or West.	Distance from Plane of Meridian, or East or West.	Distance from Plane of Meridian, or East or West.	Latitude of Plane of Meridian, or East or West.	Distance from Plane of Meridian, or East or West.	Distance from Plane of Meridian, or East or West.	Distance from Plane of Meridian, or East or West.	Latitude of Plane of Meridian, or East or West.			
25	0.906307	0.422618	1.812614	0.845236	2.718921	1.267854	3.692328	1.690472	4.531535	2.113090	60'										
26	0.906081	0.423145	1.812614	0.846290	2.718183	1.269455	3.692424	1.692580	4.530305	2.115725	58										
27	0.905856	0.423672	1.811630	0.847344	2.717445	1.271016	3.692580	1.694688	4.529075	2.118360	56										
28	0.905631	0.424199	1.811180	0.848398	2.716704	1.272597	3.692722	1.696706	4.527840	2.120995	54										
29	0.905406	0.424726	1.810730	0.849452	2.715963	1.274178	3.692864	1.698724	4.526600	2.123630	52										
30	0.905181	0.425252	1.810280	0.850506	2.715222	1.275756	3.693006	1.701008	4.525370	2.126260	50										
31	0.904956	0.425779	1.809830	0.851558	2.714481	1.277337	3.693148	1.703116	4.524136	2.128895	48										
32	0.904731	0.426305	1.809380	0.852612	2.713740	1.278915	3.693290	1.705224	4.522902	2.131525	46										
33	0.904506	0.426831	1.808930	0.853665	2.713000	1.280493	3.693432	1.707324	4.521655	2.134165	44										
34	0.904281	0.427357	1.808480	0.854718	2.712259	1.282071	3.693574	1.709440	4.520434	2.136785	42										
35	0.904056	0.427883	1.808030	0.855771	2.711518	1.283649	3.693716	1.711532	4.519165	2.139415	40										
36	0.903831	0.428409	1.807580	0.856824	2.710777	1.285227	3.693858	1.713636	4.517920	2.142045	38										
37	0.903606	0.428935	1.807130	0.857877	2.710036	1.286805	3.694000	1.715740	4.516675	2.144675	36										
38	0.903381	0.429461	1.806680	0.858930	2.709295	1.288383	3.694142	1.717840	4.515425	2.147305	34										
39	0.903156	0.430010	1.806230	0.859983	2.708554	1.289961	3.694284	1.719940	4.514175	2.149925	32										
40	0.902931	0.430536	1.805780	0.861036	2.707813	1.291539	3.694426	1.722044	4.512925	2.152555	30										
41	0.902706	0.431062	1.805330	0.862072	2.707072	1.293117	3.694568	1.724144	4.511670	2.155180	28										
42	0.902481	0.431588	1.804880	0.863122	2.706331	1.294695	3.694710	1.726244	4.510415	2.157805	26										
43	0.902256	0.432114	1.804430	0.864170	2.705590	1.296273	3.694852	1.728344	4.509160	2.160425	24										
44	0.902031	0.432640	1.803980	0.865220	2.704849	1.297851	3.694994	1.730440	4.507905	2.163050	22										
45	0.901806	0.433166	1.803530	0.866268	2.704108	1.299429	3.695136	1.732536	4.506645	2.165670	20										
46	0.901581	0.433692	1.803080	0.867316	2.703367	1.301007	3.695278	1.734636	4.505385	2.168295	18										
47	0.901356	0.434218	1.802630	0.868368	2.702626	1.302585	3.695420	1.736736	4.504120	2.170915	16										
48	0.901131	0.434744	1.802180	0.869410	2.701885	1.304163	3.695562	1.738836	4.502855	2.173535	14										
49	0.900906	0.435270	1.801730	0.870462	2.701144	1.305741	3.695704	1.740936	4.501590	2.176155	12										
50	0.900681	0.435796	1.801280	0.871508	2.700403	1.307319	3.695846	1.743036	4.500325	2.178770	10										
51	0.900456	0.436322	1.800830	0.872556	2.699662	1.308897	3.695988	1.745136	4.499055	2.181390	8										
52	0.900231	0.436848	1.800380	0.873602	2.698921	1.310475	3.696130	1.747236	4.497785	2.184005	6										
53	0.900006	0.437374	1.800000	0.874650	2.698180	1.312053	3.696272	1.749336	4.496515	2.186625	4										
54	0.899781	0.437900	1.799550	0.875696	2.697439	1.313631	3.696414	1.751436	4.495240	2.189240	2										
55	0.899556	0.438426	1.799100	0.876742	2.696698	1.315209	3.696556	1.753536	4.493970	2.191855	0										
56	0.899331	0.438952	1.798650	0.877788	2.695957	1.316787	3.696698	1.755636	4.492700	2.194470	64										
57	0.899106	0.439478	1.798200	0.878834	2.695216	1.318365	3.696840	1.757736	4.491430	2.197085											
58	0.898881	0.440004	1.797750	0.879880	2.694475	1.319943	3.696982	1.759836	4.490190	2.199700											
59	0.898656	0.440530	1.797300	0.880926	2.693734	1.321521	3.697124	1.761936	4.488950	2.202315											
60	0.898431	0.441056	1.796850	0.881972	2.693000	1.323100	3.697266	1.764036	4.487710	2.204930											



Degrees and Minutes	Measured Distances, or Hypotheses, 1, 10, 100, 1000, or 100,000				Measured Distances, or Hypotheses, 2, 20, 200, 2000, or 200,000				Measured Distances, or Hypotheses, 3, 300, 3000, 30,000, or 300,000				Measured Distances, or Hypotheses, 4, 400, 4000, 40,000, or 400,000				Measured Distances, or Hypotheses, 5, 500, 5000, 50,000, or 500,000			
	Distance From	Latitude of	Place of	Distance To	Distance From	Latitude of	Place of	Distance To	Distance From	Latitude of	Place of	Distance To	Distance From	Latitude of	Place of	Distance To	Distance From	Latitude of	Place of	Distance To
1	0.801000	0.453080	0.453080	1.799012	0.900780	0.900780	0.900780	1.799012	1.351070	1.351070	1.351070	1.351070	2.654024	1.815600	1.815600	1.815600	2.654024	4.455080	4.455080	4.455080
2	0.800748	0.452468	0.452468	1.799148	0.900616	0.900616	0.900616	1.799148	1.350924	1.350924	1.350924	1.350924	2.653860	1.815432	1.815432	1.815432	2.653860	4.454716	4.454716	4.454716
3	0.800496	0.451856	0.451856	1.799284	0.900452	0.900452	0.900452	1.799284	1.350760	1.350760	1.350760	1.350760	2.653696	1.815264	1.815264	1.815264	2.653696	4.454352	4.454352	4.454352
4	0.800244	0.451244	0.451244	1.799420	0.900288	0.900288	0.900288	1.799420	1.350596	1.350596	1.350596	1.350596	2.653532	1.815096	1.815096	1.815096	2.653532	4.453988	4.453988	4.453988
5	0.800000	0.450632	0.450632	1.799556	0.900124	0.900124	0.900124	1.799556	1.350432	1.350432	1.350432	1.350432	2.653368	1.814928	1.814928	1.814928	2.653368	4.453624	4.453624	4.453624
6	0.799752	0.450020	0.450020	1.799692	0.899960	0.899960	0.899960	1.799692	1.350268	1.350268	1.350268	1.350268	2.653204	1.814760	1.814760	1.814760	2.653204	4.453260	4.453260	4.453260
7	0.799504	0.449408	0.449408	1.799828	0.899796	0.899796	0.899796	1.799828	1.350104	1.350104	1.350104	1.350104	2.653040	1.814592	1.814592	1.814592	2.653040	4.452896	4.452896	4.452896
8	0.799256	0.448796	0.448796	1.799964	0.899632	0.899632	0.899632	1.799964	1.349940	1.349940	1.349940	1.349940	2.652876	1.814424	1.814424	1.814424	2.652876	4.452532	4.452532	4.452532
9	0.799008	0.448184	0.448184	1.800100	0.899468	0.899468	0.899468	1.800100	1.349776	1.349776	1.349776	1.349776	2.652712	1.814256	1.814256	1.814256	2.652712	4.452168	4.452168	4.452168
10	0.798760	0.447572	0.447572	1.800236	0.899304	0.899304	0.899304	1.800236	1.349612	1.349612	1.349612	1.349612	2.652548	1.814088	1.814088	1.814088	2.652548	4.451804	4.451804	4.451804
11	0.798512	0.446960	0.446960	1.800372	0.899140	0.899140	0.899140	1.800372	1.349448	1.349448	1.349448	1.349448	2.652384	1.813920	1.813920	1.813920	2.652384	4.451440	4.451440	4.451440
12	0.798264	0.446348	0.446348	1.800508	0.898976	0.898976	0.898976	1.800508	1.349284	1.349284	1.349284	1.349284	2.652220	1.813752	1.813752	1.813752	2.652220	4.451076	4.451076	4.451076
13	0.798016	0.445736	0.445736	1.800644	0.898812	0.898812	0.898812	1.800644	1.349120	1.349120	1.349120	1.349120	2.652056	1.813584	1.813584	1.813584	2.652056	4.450712	4.450712	4.450712
14	0.797768	0.445124	0.445124	1.800780	0.898648	0.898648	0.898648	1.800780	1.348956	1.348956	1.348956	1.348956	2.651892	1.813416	1.813416	1.813416	2.651892	4.450348	4.450348	4.450348
15	0.797520	0.444512	0.444512	1.800916	0.898484	0.898484	0.898484	1.800916	1.348792	1.348792	1.348792	1.348792	2.651728	1.813248	1.813248	1.813248	2.651728	4.449984	4.449984	4.449984
16	0.797272	0.443900	0.443900	1.801052	0.898320	0.898320	0.898320	1.801052	1.348628	1.348628	1.348628	1.348628	2.651564	1.813080	1.813080	1.813080	2.651564	4.449620	4.449620	4.449620
17	0.797024	0.443288	0.443288	1.801188	0.898156	0.898156	0.898156	1.801188	1.348464	1.348464	1.348464	1.348464	2.651400	1.812912	1.812912	1.812912	2.651400	4.449256	4.449256	4.449256
18	0.796776	0.442676	0.442676	1.801324	0.897992	0.897992	0.897992	1.801324	1.348300	1.348300	1.348300	1.348300	2.651236	1.812744	1.812744	1.812744	2.651236	4.448892	4.448892	4.448892
19	0.796528	0.442064	0.442064	1.801460	0.897828	0.897828	0.897828	1.801460	1.348136	1.348136	1.348136	1.348136	2.651072	1.812576	1.812576	1.812576	2.651072	4.448528	4.448528	4.448528
20	0.796280	0.441452	0.441452	1.801596	0.897664	0.897664	0.897664	1.801596	1.347972	1.347972	1.347972	1.347972	2.650908	1.812408	1.812408	1.812408	2.650908	4.448164	4.448164	4.448164
21	0.796032	0.440840	0.440840	1.801732	0.897500	0.897500	0.897500	1.801732	1.347808	1.347808	1.347808	1.347808	2.650744	1.812240	1.812240	1.812240	2.650744	4.447800	4.447800	4.447800
22	0.795784	0.440228	0.440228	1.801868	0.897336	0.897336	0.897336	1.801868	1.347644	1.347644	1.347644	1.347644	2.650580	1.812072	1.812072	1.812072	2.650580	4.447436	4.447436	4.447436
23	0.795536	0.439616	0.439616	1.802004	0.897172	0.897172	0.897172	1.802004	1.347480	1.347480	1.347480	1.347480	2.650416	1.811904	1.811904	1.811904	2.650416	4.447072	4.447072	4.447072
24	0.795288	0.439004	0.439004	1.802140	0.897008	0.897008	0.897008	1.802140	1.347316	1.347316	1.347316	1.347316	2.650252	1.811736	1.811736	1.811736	2.650252	4.446708	4.446708	4.446708
25	0.795040	0.438392	0.438392	1.802276	0.896844	0.896844	0.896844	1.802276	1.347152	1.347152	1.347152	1.347152	2.650088	1.811568	1.811568	1.811568	2.650088	4.446344	4.446344	4.446344
26	0.794792	0.437780	0.437780	1.802412	0.896680	0.896680	0.896680	1.802412	1.346988	1.346988	1.346988	1.346988	2.649924	1.811400	1.811400	1.811400	2.649924	4.445980	4.445980	4.445980
27	0.794544	0.437168	0.437168	1.802548	0.896516	0.896516	0.896516	1.802548	1.346824	1.346824	1.346824	1.346824	2.649760	1.811232	1.811232	1.811232	2.649760	4.445616	4.445616	4.445616
28	0.794296	0.436556	0.436556	1.802684	0.896352	0.896352	0.896352	1.802684	1.346660	1.346660	1.346660	1.346660	2.649596	1.811064	1.811064	1.811064	2.649596	4.445252	4.445252	4.445252
29	0.794048	0.435944	0.435944	1.802820	0.896188	0.896188	0.896188	1.802820	1.346496	1.346496	1.346496	1.346496	2.649432	1.810896	1.810896	1.810896	2.649432	4.444888	4.444888	4.444888
30	0.793800	0.435332	0.435332	1.802956	0.896024	0.896024	0.896024	1.802956	1.346332	1.346332	1.346332	1.346332	2.649268	1.810728	1.810728	1.810728	2.649268	4.444524	4.444524	4.444524
31	0.793552	0.434720	0.434720	1.803092	0.895860	0.895860	0.895860	1.803092	1.346168	1.346168	1.346168	1.346168	2.649104	1.810560	1.810560	1.810560	2.649104	4.444160	4.444160	4.444160
32	0.793304	0.434108	0.434108	1.803228	0.895696	0.895696	0.895696	1.803228	1.346004	1.346004	1.346004	1.346004	2.648940	1.810392	1.810392	1.810392	2.648940	4.443796	4.443796	4.443796
33	0.793056	0.433496	0.433496	1.803364	0.895532	0.895532	0.895532	1.803364	1.345840	1.345840	1.345840	1.345840	2.648776	1.810224	1.810224	1.810224	2.648776	4.443432	4.443432	4.443432
34	0.792808	0.432884	0.432884	1.803500	0.895368	0.895368	0.895368	1.803500	1.345676	1.345676	1.345676	1.345676	2.648612	1.810056	1.810056	1.810056	2.648612	4.443068	4.443068	4.443068
35	0.792560	0.432272	0.432272	1.803636	0.895204	0.895204	0.895204	1.803636	1.345512	1.345512	1.345512	1.345512	2.648448	1.809888	1.809888	1.809888	2.648448	4.442704	4.442704	4.442704
36	0.792312	0.431660	0.431660	1.803772	0.895040	0.895040	0.895040	1.803772	1.345348	1.345348	1.345348	1.345348	2.648284	1.809720	1.809720	1.809720	2.648284	4.442340	4.442340	4.442340
37	0.792064	0.431048	0.431048	1.803908	0.894876	0.894876	0.894876	1.803908	1.345184	1.345184	1.345184	1.345184	2.648120	1.809552	1.809552	1.809552	2.648120	4.441976	4.441976	4.441976
38	0.791816	0.430436	0.430436	1.804044	0.894712	0.894712	0.894712	1.804044	1.345020	1.345020	1.345020	1.345020	2.647956	1.809384	1.809384	1.809384	2.647956	4.441612	4.441612	4.441612
39	0.791568	0.429824	0.429824	1.804180	0.894548	0.894548	0.894548	1.804180	1.344856	1.344856	1.344856	1.344856	2.647792	1.809216	1.809216	1.809216	2.647792	4.441248	4.441248	4.441248
40	0.791320	0.429212	0.429212	1.804316	0.894384	0.894384	0.894384	1.804316	1.344692	1.344692	1.344692	1.344692	2.647628	1.809048	1.809048	1.809048	2.647628	4.440884	4.440884	4.440884
41	0.791072	0.428600	0.428600	1.804452	0.894220	0.894220	0.894220	1.804452	1.344528	1.344528	1.344528	1.344528	2.647464	1.808880	1.808880	1.808880	2.647464	4.440520	4.440520	4.440520
42	0.790824	0.427988	0.427988	1.804588	0.894056	0.894056	0.894056	1.804588	1.344364	1.344364	1.344364	1.344364	2.647300	1.808712	1.808712	1.808712	2.647300	4.440156	4.440156	4.440156
43	0.790576	0.427376	0.427376	1.804724	0.893892	0.893892	0.893892	1.804724	1.344200	1.344200	1.344200	1.344200	2.647136	1.808544	1.808544	1.808544	2.647136	4.439792	4.439792	4.4397



Degrees and Minutes.	Measured Distance, or Hypothenuse, 1, 10, 100, 1000, or 100,000.				Measured Distance, or Hypothenuse, 1, 300, 3000, 30000, or 300,000.				Measured Distance, or Hypothenuse, 1, 600, 6000, 60000, or 600,000.				Measured Distance, or Hypothenuse, 1, 900, 9000, 90000, or 900,000.			
	Distance from Place of East or West.	Latitude or South.	Distance from Place of East or West.	Distance from Place of East or West.	Distance from Place of East or West.	Latitude or South.	Distance from Place of East or West.	Distance from Place of East or West.	Distance from Place of East or West.	Latitude or South.	Distance from Place of East or West.	Distance from Place of East or West.	Distance from Place of East or West.	Latitude or South.	Distance from Place of East or West.	Distance from Place of East or West.
29	0.874619	0.484809	1.749238	0.969619	2.623867	1.454437	3.498476	1.939286	4.373095	2.429045	60	0.874619	0.484809	1.749238	0.969619	2.623867
30	0.874837	0.485534	1.748674	0.970636	2.628200	1.455956	3.497348	1.941272	4.371885	2.426590	61	0.874837	0.485534	1.748674	0.970636	2.628200
4	0.874056	0.485927	1.748110	0.971654	2.632165	1.457481	3.496220	1.943808	4.370735	2.425135	56	0.874056	0.485927	1.748110	0.971654	2.632165
4	0.873772	0.486333	1.747544	0.972670	2.636130	1.459000	3.495088	1.946340	4.369580	2.423675	54	0.873772	0.486333	1.747544	0.972670	2.636130
8	0.873489	0.486743	1.746978	0.973686	2.640105	1.460519	3.493956	1.948872	4.368431	2.422215	52	0.873489	0.486743	1.746978	0.973686	2.640105
10	0.873205	0.487151	1.746410	0.974702	2.644180	1.462038	3.492830	1.951404	4.367282	2.420755	50	0.873205	0.487151	1.746410	0.974702	2.644180
12	0.872922	0.487559	1.745844	0.975718	2.648255	1.463557	3.491698	1.953932	4.366133	2.419295	48	0.872922	0.487559	1.745844	0.975718	2.648255
14	0.872638	0.487967	1.745276	0.976734	2.652330	1.465076	3.490552	1.956460	4.364984	2.417835	46	0.872638	0.487967	1.745276	0.976734	2.652330
16	0.872353	0.488375	1.744708	0.977750	2.656405	1.466595	3.489413	1.958988	4.363835	2.416375	44	0.872353	0.488375	1.744708	0.977750	2.656405
18	0.872069	0.488783	1.744138	0.978766	2.660480	1.468114	3.488267	1.961516	4.362686	2.414915	42	0.872069	0.488783	1.744138	0.978766	2.660480
20	0.871784	0.489191	1.743568	0.979782	2.664555	1.469633	3.487130	1.964048	4.361537	2.413455	40	0.871784	0.489191	1.743568	0.979782	2.664555
22	0.871499	0.490396	1.742998	0.980792	2.668630	1.471152	3.485989	1.966570	4.360388	2.411995	38	0.871499	0.490396	1.742998	0.980792	2.668630
24	0.871213	0.490803	1.742428	0.981806	2.672705	1.472673	3.484852	1.969092	4.359239	2.410535	36	0.871213	0.490803	1.742428	0.981806	2.672705
26	0.870928	0.491210	1.741858	0.982820	2.676780	1.474194	3.483715	1.971614	4.358090	2.409075	34	0.870928	0.491210	1.741858	0.982820	2.676780
28	0.870642	0.491617	1.741288	0.983834	2.680855	1.475715	3.482578	1.974136	4.356941	2.407615	32	0.870642	0.491617	1.741288	0.983834	2.680855
30	0.870356	0.492023	1.740718	0.984848	2.684930	1.477236	3.481440	1.976658	4.355792	2.406155	30	0.870356	0.492023	1.740718	0.984848	2.684930
32	0.870069	0.492429	1.740138	0.985862	2.689005	1.478757	3.480303	1.979180	4.354643	2.404695	28	0.870069	0.492429	1.740138	0.985862	2.689005
34	0.869782	0.492835	1.739558	0.986876	2.693080	1.480278	3.479166	1.981702	4.353494	2.403235	26	0.869782	0.492835	1.739558	0.986876	2.693080
36	0.869495	0.493241	1.738978	0.987890	2.697155	1.481799	3.478029	1.984224	4.352345	2.401775	24	0.869495	0.493241	1.738978	0.987890	2.697155
38	0.869207	0.493647	1.738398	0.988904	2.701230	1.483320	3.476892	1.986746	4.351196	2.400315	22	0.869207	0.493647	1.738398	0.988904	2.701230
40	0.868919	0.494053	1.737838	0.989906	2.705305	1.484859	3.475757	1.989268	4.350147	2.398855	20	0.868919	0.494053	1.737838	0.989906	2.705305
42	0.868631	0.494458	1.737282	0.990916	2.709380	1.486374	3.474624	1.991790	4.349098	2.397395	18	0.868631	0.494458	1.737282	0.990916	2.709380
44	0.868343	0.494859	1.736726	0.991926	2.713455	1.487899	3.473492	1.994312	4.348049	2.395935	16	0.868343	0.494859	1.736726	0.991926	2.713455
46	0.868055	0.495260	1.736168	0.992938	2.717530	1.489424	3.472361	1.996834	4.347000	2.394475	14	0.868055	0.495260	1.736168	0.992938	2.717530
48	0.867767	0.495664	1.735609	0.993950	2.721605	1.490948	3.471230	1.999356	4.345951	2.393015	12	0.867767	0.495664	1.735609	0.993950	2.721605
50	0.867478	0.496067	1.735052	0.994965	2.725680	1.492473	3.470099	2.001878	4.344902	2.391555	10	0.867478	0.496067	1.735052	0.994965	2.725680
52	0.867186	0.496468	1.734492	0.995986	2.729755	1.493998	3.468968	2.004400	4.343853	2.390095	8	0.867186	0.496468	1.734492	0.995986	2.729755
54	0.866894	0.496869	1.733935	0.996998	2.733830	1.495523	3.467837	2.006922	4.342804	2.388635	6	0.866894	0.496869	1.733935	0.996998	2.733830
56	0.866601	0.497269	1.733378	0.997998	2.737905	1.497048	3.466706	2.009444	4.341755	2.387175	4	0.866601	0.497269	1.733378	0.997998	2.737905
58	0.866308	0.497669	1.732822	0.998998	2.741980	1.498573	3.465575	2.011966	4.340706	2.385715	2	0.866308	0.497669	1.732822	0.998998	2.741980
60	0.866025	0.500000	1.732265	1.000000	2.746055	1.732265	4.340100	2.000000	4.340100	2.385125	0	0.866025	0.500000	1.732265	1.000000	2.746055





Distance and Minutes.	Measured Distance, or Hypotenuse, of 10, 100, 1000, or 100,000.				Measured Distance, or Hypotenuse, of 1,000, 200, 2000, or 200,000.				Measured Distance, or Hypotenuse, of 10,000, 300, 3000, or 300,000.				Measured Distance, or Hypotenuse, of 100,000, 400, 4000, or 400,000.				Distance and Minutes.
	Distance From Plane of Latitude or South or East or West	Distance From Plane of Latitude or South or East or West	Distance From Plane of Latitude or South or East or West	Distance From Plane of Latitude or South or East or West	Distance From Plane of Latitude or South or East or West	Distance From Plane of Latitude or South or East or West	Distance From Plane of Latitude or South or East or West	Distance From Plane of Latitude or South or East or West	Distance From Plane of Latitude or South or East or West	Distance From Plane of Latitude or South or East or West	Distance From Plane of Latitude or South or East or West	Distance From Plane of Latitude or South or East or West	Distance From Plane of Latitude or South or East or West	Distance From Plane of Latitude or South or East or West	Distance From Plane of Latitude or South or East or West	Distance From Plane of Latitude or South or East or West	
10	0.857167	0.515036	1.714334	1.030076	2.571501	1.545114	3.428685	2.060132	4.285335	2.575100	60						
20	0.856867	0.515035	1.713734	1.031072	2.569601	1.544608	3.427403	2.062144	4.284335	2.575860	55						
30	0.856567	0.515035	1.713134	1.032070	2.567601	1.544103	3.426103	2.063140	4.283335	2.576615	50						
40	0.856267	0.515035	1.712534	1.033068	2.565601	1.543599	3.424803	2.064132	4.282335	2.577370	45						
50	0.855967	0.515035	1.711934	1.034066	2.563601	1.543094	3.423503	2.065124	4.281335	2.578125	40						
60	0.855667	0.515035	1.711334	1.035064	2.561601	1.542589	3.422203	2.066116	4.280335	2.578880	35						
70	0.855367	0.515035	1.710734	1.036062	2.559601	1.542084	3.420903	2.067108	4.279335	2.579635	30						
80	0.855067	0.515035	1.710134	1.037060	2.557601	1.541579	3.419603	2.068100	4.278335	2.580390	25						
90	0.854767	0.515035	1.709534	1.038058	2.555601	1.541074	3.418303	2.069092	4.277335	2.581145	20						
100	0.854467	0.515035	1.708934	1.039056	2.553601	1.540569	3.417003	2.070084	4.276335	2.581900	15						
110	0.854167	0.515035	1.708334	1.040054	2.551601	1.540064	3.415703	2.071076	4.275335	2.582655	10						
120	0.853867	0.515035	1.707734	1.041052	2.549601	1.539559	3.414403	2.072068	4.274335	2.583410	5						
130	0.853567	0.515035	1.707134	1.042050	2.547601	1.539054	3.413103	2.073060	4.273335	2.584165							
140	0.853267	0.515035	1.706534	1.043048	2.545601	1.538549	3.411803	2.074052	4.272335	2.584920							
150	0.852967	0.515035	1.705934	1.044046	2.543601	1.538044	3.410503	2.075044	4.271335	2.585675							
160	0.852667	0.515035	1.705334	1.045044	2.541601	1.537539	3.409203	2.076036	4.270335	2.586430							
170	0.852367	0.515035	1.704734	1.046042	2.539601	1.537034	3.407903	2.077028	4.269335	2.587185							
180	0.852067	0.515035	1.704134	1.047040	2.537601	1.536529	3.406603	2.078020	4.268335	2.587940							
190	0.851767	0.515035	1.703534	1.048038	2.535601	1.536024	3.405303	2.079012	4.267335	2.588695							
200	0.851467	0.515035	1.702934	1.049036	2.533601	1.535519	3.404003	2.080004	4.266335	2.589450							
210	0.851167	0.515035	1.702334	1.050034	2.531601	1.535014	3.402703	2.081000	4.265335	2.590205							
220	0.850867	0.515035	1.701734	1.051032	2.529601	1.534509	3.401403	2.082000	4.264335	2.590960							
230	0.850567	0.515035	1.701134	1.052030	2.527601	1.534004	3.400103	2.083000	4.263335	2.591715							
240	0.850267	0.515035	1.700534	1.053028	2.525601	1.533499	3.398803	2.084000	4.262335	2.592470							
250	0.849967	0.515035	1.700000	1.054026	2.523601	1.532994	3.397503	2.085000	4.261335	2.593225							
260	0.849667	0.515035	1.699466	1.055024	2.521601	1.532489	3.396203	2.086000	4.260335	2.593980							
270	0.849367	0.515035	1.698932	1.056022	2.519601	1.531984	3.394903	2.087000	4.259335	2.594735							
280	0.849067	0.515035	1.698398	1.057020	2.517601	1.531479	3.393603	2.088000	4.258335	2.595490							
290	0.848767	0.515035	1.697864	1.058018	2.515601	1.530974	3.392303	2.089000	4.257335	2.596245							
300	0.848467	0.515035	1.697330	1.059016	2.513601	1.530469	3.391003	2.090000	4.256335	2.597000							
310	0.848167	0.515035	1.696796	1.060014	2.511601	1.529964	3.389703	2.091000	4.255335	2.597755							
320	0.847867	0.515035	1.696262	1.061012	2.509601	1.529459	3.388403	2.092000	4.254335	2.598510							
330	0.847567	0.515035	1.695728	1.062010	2.507601	1.528954	3.387103	2.093000	4.253335	2.599265							
340	0.847267	0.515035	1.695194	1.063008	2.505601	1.528449	3.385803	2.094000	4.252335	2.599970							
350	0.846967	0.515035	1.694660	1.064006	2.503601	1.527944	3.384503	2.095000	4.251335	2.600725							
360	0.846667	0.515035	1.694126	1.065004	2.501601	1.527439	3.383203	2.096000	4.250335	2.601480							
370	0.846367	0.515035	1.693592	1.066002	2.500000	1.526934	3.381903	2.097000	4.249335	2.602235							
380	0.846067	0.515035	1.693058	1.067000	2.498000	1.526429	3.380603	2.098000	4.248335	2.602990							
390	0.845767	0.515035	1.692524	1.068000	2.496000	1.525924	3.379303	2.099000	4.247335	2.603745							
400	0.845467	0.515035	1.691990	1.069000	2.494000	1.525419	3.378003	2.100000	4.246335	2.604500							
410	0.845167	0.515035	1.691456	1.070000	2.492000	1.524914	3.376703	2.101000	4.245335	2.605255							
420	0.844867	0.515035	1.690922	1.071000	2.490000	1.524409	3.375403	2.102000	4.244335	2.606010							
430	0.844567	0.515035	1.690388	1.072000	2.488000	1.523904	3.374103	2.103000	4.243335	2.606765							
440	0.844267	0.515035	1.689854	1.073000	2.486000	1.523399	3.372803	2.104000	4.242335	2.607520							
450	0.843967	0.515035	1.689320	1.074000	2.484000	1.522894	3.371503	2.105000	4.241335	2.608275							
460	0.843667	0.515035	1.688786	1.075000	2.482000	1.522389	3.370203	2.106000	4.240335	2.609030							
470	0.843367	0.515035	1.688252	1.076000	2.480000	1.521884	3.368903	2.107000	4.239335	2.609785							
480	0.843067	0.515035	1.687718	1.077000	2.478000	1.521379	3.367603	2.108000	4.238335	2.610540							
490	0.842767	0.515035	1.687184	1.078000	2.476000	1.520874	3.366303	2.109000	4.237335	2.611295							
500	0.842467	0.515035	1.686650	1.079000	2.474000	1.520369	3.365003	2.110000	4.236335	2.612050							
510	0.842167	0.515035	1.686116	1.080000	2.472000	1.519864	3.363703	2.111000	4.235335	2.612805							
520	0.841867	0.515035	1.685582	1.081000	2.470000	1.519359	3.362403	2.112000	4.234335	2.613560							
530	0.841567	0.515035	1.685048	1.082000	2.468000	1.518854	3.361103	2.113000	4.233335	2.614315							
540	0.841267	0.515035	1.684514	1.083000	2.466000	1.518349	3.359803	2.114000	4.232335	2.615070							
550	0.840967	0.515035	1.683980	1.084000	2.464000	1.517844	3.358503	2.115000	4.231335	2.615825							
560	0.840667	0.515035	1.683446	1.085000	2.462000	1.517339	3.357203	2.116000	4.230335	2.616580							
570	0.840367	0.515035	1.682912	1.086000	2.460000	1.516834	3.355903	2.117000	4.229335	2.617335							
580	0.840067	0.515035	1.682378	1.087000	2.458000	1.516329	3.354603	2.118000	4.228335	2.618090							
590	0.839767	0.515035	1.681844	1.088000	2.456000	1.515824	3.353303	2.119000	4.227335	2.618845							
600	0.839467	0.515035	1.681310	1.089000	2.454000	1.515319	3.352003	2.120000	4.226335	2.619600							

### TRAVERSE TABLES.

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Degrees and Minutes	Measured Distance, or Hypothenuse, 1, 10, 100, 1000, 10000, or 100,000.				Measured Distance, or Hypothenuse, 50, 500, 5000, 50,000, or 500,000.				Measured Distance, or Hypothenuse, 4, 40, 400, 4000, or 400,000.				Measured Distance, or Hypothenuse, 5, 50, 500, 5000, or 500,000.				Degrees and Minutes
	Distance from Place of Latitude or East	Distance from Place of Latitude or West	Distance from Place of Latitude or East	Distance from Place of Latitude or West	Distance from Place of Latitude or East	Distance from Place of Latitude or West	Distance from Place of Latitude or East	Distance from Place of Latitude or West	Distance from Place of Latitude or East	Distance from Place of Latitude or West	Distance from Place of Latitude or East	Distance from Place of Latitude or West	Distance from Place of Latitude or East	Distance from Place of Latitude or West	Distance from Place of Latitude or East	Distance from Place of Latitude or West	
1	0.893637	0.559192	1.658074	1.118384	2.487111	1.677573	3.316148	2.236758	4.146165	2.795960	80						
2	0.893712	0.559675	1.657494	1.118360	2.486136	1.677095	3.314848	2.236758	4.145860	2.795375	58						
3	0.893786	0.560157	1.656914	1.118336	2.485161	1.676617	3.313549	2.236758	4.145562	2.794790	56						
4	0.893860	0.560639	1.656334	1.118312	2.484186	1.676139	3.312250	2.236758	4.145264	2.794205	54						
5	0.893934	0.561120	1.655754	1.118288	2.483211	1.675661	3.310951	2.236758	4.144966	2.793620	52						
6	0.894008	0.561602	1.655174	1.118264	2.482236	1.675183	3.309652	2.236758	4.144668	2.793035	50						
7	0.894082	0.562083	1.654594	1.118240	2.481261	1.674705	3.308353	2.236758	4.144370	2.792450	48						
8	0.894156	0.562564	1.654014	1.118216	2.480286	1.674227	3.307054	2.236758	4.144072	2.791865	46						
9	0.894230	0.563045	1.653434	1.118192	2.479311	1.673749	3.305755	2.236758	4.143774	2.791280	44						
10	0.894304	0.563526	1.652854	1.118168	2.478336	1.673271	3.304456	2.236758	4.143476	2.790695	42						
11	0.894378	0.564007	1.652274	1.118144	2.477361	1.672793	3.303157	2.236758	4.143178	2.790110	40						
12	0.894452	0.564488	1.651694	1.118120	2.476386	1.672315	3.301858	2.236758	4.142880	2.789525	38						
13	0.894526	0.564969	1.651114	1.118096	2.475411	1.671837	3.300559	2.236758	4.142582	2.788940	36						
14	0.894600	0.565450	1.650534	1.118072	2.474436	1.671359	3.299260	2.236758	4.142284	2.788355	34						
15	0.894674	0.565931	1.649954	1.118048	2.473461	1.670881	3.297961	2.236758	4.141986	2.787770	32						
16	0.894748	0.566412	1.649374	1.118024	2.472486	1.670403	3.296662	2.236758	4.141688	2.787185	30						
17	0.894822	0.566893	1.648794	1.117999	2.471511	1.669925	3.295363	2.236758	4.141390	2.786600	28						
18	0.894896	0.567374	1.648214	1.117975	2.470536	1.669447	3.294064	2.236758	4.141092	2.786015	26						
19	0.894970	0.567855	1.647634	1.117951	2.469561	1.668969	3.292765	2.236758	4.140794	2.785430	24						
20	0.895044	0.568336	1.647054	1.117927	2.468586	1.668491	3.291466	2.236758	4.140496	2.784845	22						
21	0.895118	0.568817	1.646474	1.117903	2.467611	1.668013	3.290167	2.236758	4.140198	2.784260	20						
22	0.895192	0.569298	1.645894	1.117879	2.466636	1.667535	3.288868	2.236758	4.139900	2.783675	18						
23	0.895266	0.569779	1.645314	1.117855	2.465661	1.667057	3.287569	2.236758	4.139602	2.783090	16						
24	0.895340	0.570260	1.644734	1.117831	2.464686	1.666579	3.286270	2.236758	4.139304	2.782505	14						
25	0.895414	0.570741	1.644154	1.117807	2.463711	1.666101	3.284971	2.236758	4.139006	2.781920	12						
26	0.895488	0.571222	1.643574	1.117783	2.462736	1.665623	3.283672	2.236758	4.138708	2.781335	10						
27	0.895562	0.571703	1.642994	1.117759	2.461761	1.665145	3.282373	2.236758	4.138410	2.780750	8						
28	0.895636	0.572184	1.642414	1.117735	2.460786	1.664667	3.281074	2.236758	4.138112	2.780165	6						
29	0.895710	0.572665	1.641834	1.117711	2.459811	1.664189	3.279775	2.236758	4.137814	2.779580	4						
30	0.895784	0.573146	1.641254	1.117687	2.458836	1.663711	3.278476	2.236758	4.137516	2.778995	2						
31	0.895858	0.573627	1.640674	1.117663	2.457861	1.663233	3.277177	2.236758	4.137218	2.778410							
32	0.895932	0.574108	1.640094	1.117639	2.456886	1.662755	3.275878	2.236758	4.136920	2.777825							
33	0.896006	0.574589	1.639514	1.117615	2.455911	1.662277	3.274579	2.236758	4.136622	2.777240							
34	0.896080	0.575070	1.638934	1.117591	2.454936	1.661799	3.273280	2.236758	4.136324	2.776655							
35	0.896154	0.575551	1.638354	1.117567	2.453961	1.661321	3.271981	2.236758	4.136026	2.776070							
36	0.896228	0.576032	1.637774	1.117543	2.452986	1.660843	3.270682	2.236758	4.135728	2.775485							
37	0.896302	0.576513	1.637194	1.117519	2.452011	1.660365	3.269383	2.236758	4.135430	2.774900							
38	0.896376	0.576994	1.636614	1.117495	2.451036	1.659887	3.268084	2.236758	4.135132	2.774315							
39	0.896450	0.577475	1.636034	1.117471	2.450061	1.659409	3.266785	2.236758	4.134834	2.773730							
40	0.896524	0.577956	1.635454	1.117447	2.449086	1.658931	3.265486	2.236758	4.134536	2.773145							
41	0.896598	0.578437	1.634874	1.117423	2.448111	1.658453	3.264187	2.236758	4.134238	2.772560							
42	0.896672	0.578918	1.634294	1.117399	2.447136	1.657975	3.262888	2.236758	4.133940	2.771975							
43	0.896746	0.579399	1.633714	1.117375	2.446161	1.657497	3.261589	2.236758	4.133642	2.771390							
44	0.896820	0.579880	1.633134	1.117351	2.445186	1.657019	3.260290	2.236758	4.133344	2.770805							
45	0.896894	0.580361	1.632554	1.117327	2.444211	1.656541	3.258991	2.236758	4.133046	2.770220							
46	0.896968	0.580842	1.631974	1.117303	2.443236	1.656063	3.257692	2.236758	4.132748	2.769635							
47	0.897042	0.581323	1.631394	1.117279	2.442261	1.655585	3.256393	2.236758	4.132450	2.769050							
48	0.897116	0.581804	1.630814	1.117255	2.441286	1.655107	3.255094	2.236758	4.132152	2.768465							
49	0.897190	0.582285	1.630234	1.117231	2.440311	1.654629	3.253795	2.236758	4.131854	2.767880							
50	0.897264	0.582766	1.629654	1.117207	2.439336	1.654151	3.252496	2.236758	4.131556	2.767295							
51	0.897338	0.583247	1.629074	1.117183	2.438361	1.653673	3.251197	2.236758	4.131258	2.766710							
52	0.897412	0.583728	1.628494	1.117159	2.437386	1.653195	3.249898	2.236758	4.130960	2.766125							
53	0.897486	0.584209	1.627914	1.117135	2.436411	1.652717	3.248599	2.236758	4.130662	2.765540							
54	0.897560	0.584690	1.627334	1.117111	2.435436	1.652239	3.247300	2.236758	4.130364	2.764955							
55	0.897634	0.585171	1.626754	1.117087	2.434461	1.651761	3.246001	2.236758	4.130066	2.764370							
56	0.897708	0.585652	1.626174	1.117063	2.433486	1.651283	3.244702	2.236758	4.129768	2.763785							
57	0.897782	0.586133	1.625594	1.117039	2.432511	1.650805	3.243403	2.236758	4.129470	2.763200							
58	0.897856	0.586614	1.625014	1.117015	2.431536	1.650327	3.242104	2.236758	4.129172	2.762615							
59	0.897930	0.587095	1.624434	1.116991	2.430561	1.649849	3.240805	2.236758	4.128874	2.762030							
60	0.898004	0.587576	1.623854	1.116967	2.429586	1.649371	3.239506	2.236758	4.128576	2.761445							



Degrees and Minutes.	Measured Distance, or Hypothenuse, from 1, 10, 100, 1000, 10000, or 100,000.				Measured Distance, or Hypothenuse, from 1, 10, 100, 1000, 10000, or 100,000.				Measured Distance, or Hypothenuse, from 1, 10, 100, 1000, 10000, or 100,000.				Measured Distance, or Hypothenuse, from 1, 10, 100, 1000, 10000, or 100,000.				Measured Distance, or Hypothenuse, from 1, 10, 100, 1000, 10000, or 100,000.				Degrees and Minutes.		
	Distance from North or South.	Latitude of Place from North or South.	Distance from East or West.	Latitude of Place from East or West.	Distance from North or South.	Latitude of Place from North or South.	Distance from East or West.	Latitude of Place from East or West.	Distance from North or South.	Latitude of Place from North or South.	Distance from East or West.	Latitude of Place from East or West.	Distance from North or South.	Latitude of Place from North or South.	Distance from East or West.	Latitude of Place from East or West.	Distance from North or South.	Latitude of Place from North or South.	Distance from East or West.	Latitude of Place from East or West.			
28	0.809017	0.587785	1.618034	1.176570	2.427051	1.753855	8.226068	2.351140	4.045085	2.983925	4.045085	2.983925	8.226068	2.351140	4.045085	2.983925	4.045085	2.983925	8.226068	2.351140	4.045085	2.983925	28
29	0.808674	0.586255	1.617848	1.176510	2.426022	1.753765	8.226496	2.350920	4.043870	2.984126	4.043870	2.984126	8.226496	2.350920	4.043870	2.984126	4.043870	2.984126	8.226496	2.350920	4.043870	2.984126	29
30	0.808332	0.584726	1.617664	1.176452	2.424996	1.753678	8.226928	2.350704	4.042654	2.984266	4.042654	2.984266	8.226928	2.350704	4.042654	2.984266	4.042654	2.984266	8.226928	2.350704	4.042654	2.984266	30
31	0.807990	0.583196	1.617578	1.176392	2.423967	1.753588	8.227360	2.350488	4.041438	2.984404	4.041438	2.984404	8.227360	2.350488	4.041438	2.984404	4.041438	2.984404	8.227360	2.350488	4.041438	2.984404	31
32	0.807647	0.581666	1.617492	1.176332	2.422941	1.753498	8.227792	2.350272	4.040222	2.984542	4.040222	2.984542	8.227792	2.350272	4.040222	2.984542	4.040222	2.984542	8.227792	2.350272	4.040222	2.984542	32
33	0.807305	0.580136	1.617406	1.176272	2.421915	1.753408	8.228224	2.350056	4.039006	2.984680	4.039006	2.984680	8.228224	2.350056	4.039006	2.984680	4.039006	2.984680	8.228224	2.350056	4.039006	2.984680	33
34	0.806963	0.578606	1.617320	1.176212	2.420889	1.753318	8.228656	2.349840	4.037790	2.984818	4.037790	2.984818	8.228656	2.349840	4.037790	2.984818	4.037790	2.984818	8.228656	2.349840	4.037790	2.984818	34
35	0.806621	0.577076	1.617234	1.176152	2.419863	1.753228	8.229088	2.349624	4.036574	2.984956	4.036574	2.984956	8.229088	2.349624	4.036574	2.984956	4.036574	2.984956	8.229088	2.349624	4.036574	2.984956	35
36	0.806279	0.575546	1.617148	1.176092	2.418837	1.753138	8.229520	2.349408	4.035358	2.985094	4.035358	2.985094	8.229520	2.349408	4.035358	2.985094	4.035358	2.985094	8.229520	2.349408	4.035358	2.985094	36
37	0.805937	0.574016	1.617062	1.176032	2.417811	1.753048	8.229952	2.349192	4.034142	2.985232	4.034142	2.985232	8.229952	2.349192	4.034142	2.985232	4.034142	2.985232	8.229952	2.349192	4.034142	2.985232	37
38	0.805595	0.572486	1.616976	1.175972	2.416785	1.752958	8.230384	2.348976	4.032926	2.985370	4.032926	2.985370	8.230384	2.348976	4.032926	2.985370	4.032926	2.985370	8.230384	2.348976	4.032926	2.985370	38
39	0.805253	0.570956	1.616890	1.175912	2.415759	1.752868	8.230816	2.348760	4.031710	2.985508	4.031710	2.985508	8.230816	2.348760	4.031710	2.985508	4.031710	2.985508	8.230816	2.348760	4.031710	2.985508	39
40	0.804911	0.569426	1.616804	1.175852	2.414733	1.752778	8.231248	2.348544	4.030494	2.985646	4.030494	2.985646	8.231248	2.348544	4.030494	2.985646	4.030494	2.985646	8.231248	2.348544	4.030494	2.985646	40
41	0.804569	0.567896	1.616718	1.175792	2.413707	1.752688	8.231680	2.348328	4.029278	2.985784	4.029278	2.985784	8.231680	2.348328	4.029278	2.985784	4.029278	2.985784	8.231680	2.348328	4.029278	2.985784	41
42	0.804227	0.566366	1.616632	1.175732	2.412681	1.752598	8.232112	2.348112	4.028062	2.985922	4.028062	2.985922	8.232112	2.348112	4.028062	2.985922	4.028062	2.985922	8.232112	2.348112	4.028062	2.985922	42
43	0.803885	0.564836	1.616546	1.175672	2.411655	1.752508	8.232544	2.347896	4.026846	2.986060	4.026846	2.986060	8.232544	2.347896	4.026846	2.986060	4.026846	2.986060	8.232544	2.347896	4.026846	2.986060	43
44	0.803543	0.563306	1.616460	1.175612	2.410629	1.752418	8.232976	2.347680	4.025630	2.986198	4.025630	2.986198	8.232976	2.347680	4.025630	2.986198	4.025630	2.986198	8.232976	2.347680	4.025630	2.986198	44
45	0.803201	0.561776	1.616374	1.175552	2.409603	1.752328	8.233408	2.347464	4.024414	2.986336	4.024414	2.986336	8.233408	2.347464	4.024414	2.986336	4.024414	2.986336	8.233408	2.347464	4.024414	2.986336	45
46	0.802859	0.560246	1.616288	1.175492	2.408577	1.752238	8.233840	2.347248	4.023198	2.986474	4.023198	2.986474	8.233840	2.347248	4.023198	2.986474	4.023198	2.986474	8.233840	2.347248	4.023198	2.986474	46
47	0.802517	0.558716	1.616202	1.175432	2.407551	1.752148	8.234272	2.347032	4.021982	2.986612	4.021982	2.986612	8.234272	2.347032	4.021982	2.986612	4.021982	2.986612	8.234272	2.347032	4.021982	2.986612	47
48	0.802175	0.557186	1.616116	1.175372	2.406525	1.752058	8.234704	2.346816	4.020766	2.986750	4.020766	2.986750	8.234704	2.346816	4.020766	2.986750	4.020766	2.986750	8.234704	2.346816	4.020766	2.986750	48
49	0.801833	0.555656	1.616030	1.175312	2.405499	1.751968	8.235136	2.346600	4.019550	2.986888	4.019550	2.986888	8.235136	2.346600	4.019550	2.986888	4.019550	2.986888	8.235136	2.346600	4.019550	2.986888	49
50	0.801491	0.554126	1.615944	1.175252	2.404473	1.751878	8.235568	2.346384	4.018334	2.987026	4.018334	2.987026	8.235568	2.346384	4.018334	2.987026	4.018334	2.987026	8.235568	2.346384	4.018334	2.987026	50
51	0.801149	0.552596	1.615858	1.175192	2.403447	1.751788	8.235992	2.346168	4.017118	2.987164	4.017118	2.987164	8.235992	2.346168	4.017118	2.987164	4.017118	2.987164	8.235992	2.346168	4.017118	2.987164	51
52	0.800807	0.551066	1.615772	1.175132	2.402421	1.751698	8.236424	2.345952	4.015902	2.987302	4.015902	2.987302	8.236424	2.345952	4.015902	2.987302	4.015902	2.987302	8.236424	2.345952	4.015902	2.987302	52
53	0.800465	0.549536	1.615686	1.175072	2.401395	1.751608	8.236856	2.345736	4.014686	2.987440	4.014686	2.987440	8.236856	2.345736	4.014686	2.987440	4.014686	2.987440	8.236856	2.345736	4.014686	2.987440	53
54	0.800123	0.548006	1.615600	1.175012	2.400369	1.751518	8.237288	2.345520	4.013470	2.987578	4.013470	2.987578	8.237288	2.345520	4.013470	2.987578	4.013470	2.987578	8.237288	2.345520	4.013470	2.987578	54
55	0.799781	0.546476	1.615514	1.174952	2.399343	1.751428	8.237720	2.345304	4.012254	2.987716	4.012254	2.987716	8.237720	2.345304	4.012254	2.987716	4.012254	2.987716	8.237720	2.345304	4.012254	2.987716	55
56	0.799439	0.544946	1.615428	1.174892	2.398317	1.751338	8.238152	2.345088	4.011038	2.987854	4.011038	2.987854	8.238152	2.345088	4.011038	2.987854	4.011038	2.987854	8.238152	2.345088	4.011038	2.987854	56
57	0.799097	0.543416	1.615342	1.174832	2.397291	1.751248	8.238584	2.344872	4.009822	2.987992	4.009822	2.987992	8.238584	2.344872	4.009822	2.987992	4.009822	2.987992	8.238584	2.344872	4.009822	2.987992	57
58	0.798755	0.541886	1.615256	1.174772	2.396265	1.751158	8.239016	2.344656	4.008606	2.988130	4.008606	2.988130	8.239016	2.344656	4.008606	2.988130	4.008606	2.988130	8.239016	2.344656	4.008606	2.988130	58
59	0.798413	0.540356	1.615170	1.174712	2.395239	1.751068	8.239448	2.344440	4.007390	2.988268	4.007390	2.988268	8.239448	2.344440	4.007390	2.988268	4.007390	2.988268	8.239448	2.344440	4.007390	2.988268	59
60	0.798071	0.538826	1.615084	1.174652	2.394213	1.750978	8.239880	2.344224	4.006174	2.988406	4.006174	2.988406	8.239880	2.344224	4.006174	2.988406	4.006174	2.988406	8.239880	2.344224	4.006174	2.988406	60

Degrees and Minutes.	Measured Distance, or Hypothenuse, 1, 10, 100, 1000, 10,000, or 100,000.				Measured Distance, or Hypothenuse, 2, 20, 200, 2000, 20,000, or 200,000.				Measured Distance, or Hypothenuse, 3, 30, 300, 3000, 30,000, or 300,000.				Measured Distance, or Hypothenuse, 4, 40, 400, 4000, 40,000, or 400,000.				Measured Distance, or Hypothenuse, 5, 50, 500, 5000, 50,000, or 500,000.			
	Distance from North or South.	Plane of Meridian.	Latitude or Longitude.	Distance from North or South.	Distance from North or South.	Plane of Meridian.	Latitude or Longitude.	Distance from North or South.	Distance from North or South.	Plane of Meridian.	Latitude or Longitude.	Distance from North or South.	Distance from North or South.	Plane of Meridian.	Latitude or Longitude.	Distance from North or South.	Distance from North or South.	Plane of Meridian.	Latitude or Longitude.	
97	0.799635	0.601815	1.597270	1.203630	2.395906	1.805445	3.194540	2.407260	8.993175	3.009075	607									
98	0.799285	0.602270	1.596570	1.204553	2.394855	1.806837	3.193140	2.409116	8.991425	3.009125	58									
99	0.798934	0.602734	1.595658	1.205486	2.393802	1.808229	3.191736	2.410972	8.989670	3.013715	56									
100	0.798583	0.603208	1.594766	1.206416	2.392749	1.809624	3.190332	2.412832	8.987915	3.016040	54									
101	0.798232	0.603671	1.593844	1.207342	2.391696	1.811013	3.188938	2.414684	8.986160	3.018355	52									
102	0.797881	0.604135	1.592923	1.208270	2.390643	1.812414	3.187524	2.416540	8.984405	3.020675	50									
103	0.797530	0.604598	1.592001	1.209198	2.389587	1.813797	3.186116	2.418396	8.982645	3.022996	48									
104	0.797178	0.605062	1.591078	1.210124	2.388532	1.815186	3.184712	2.420245	8.980880	3.025310	46									
105	0.796826	0.605525	1.590154	1.211050	2.387475	1.816575	3.183300	2.422100	8.979125	3.027625	44									
106	0.796473	0.605988	1.589230	1.211976	2.386419	1.817964	3.181886	2.423952	8.977365	3.029940	42									
107	0.796121	0.606451	1.588306	1.212902	2.385363	1.819353	3.180468	2.425804	8.975605	3.032255	40									
108	0.795767	0.606913	1.587382	1.213826	2.384301	1.820739	3.179048	2.427652	8.973835	3.034565	38									
109	0.795414	0.607375	1.586458	1.214750	2.383242	1.822125	3.177636	2.429500	8.972070	3.036875	36									
110	0.795061	0.607837	1.585533	1.215674	2.382183	1.823511	3.176224	2.431348	8.970305	3.039185	34									
111	0.794707	0.608299	1.584614	1.216598	2.381121	1.824897	3.174828	2.433196	8.968535	3.041495	32									
112	0.794353	0.608761	1.583690	1.217522	2.380059	1.826283	3.173412	2.435044	8.966765	3.043805	30									
113	0.793999	0.609222	1.582765	1.218444	2.378997	1.827666	3.171996	2.436888	8.964995	3.046110	28									
114	0.793644	0.609684	1.581840	1.219368	2.377932	1.829052	3.170576	2.438736	8.963220	3.048420	26									
115	0.793289	0.610145	1.580915	1.220290	2.376867	1.830435	3.169156	2.440580	8.961445	3.050725	24									
116	0.792934	0.610606	1.580000	1.221212	2.375802	1.831818	3.167736	2.442424	8.959670	3.053030	22									
117	0.792579	0.611066	1.579085	1.222132	2.374737	1.833198	3.166316	2.444264	8.957895	3.055335	20									
118	0.792223	0.611527	1.578169	1.223054	2.373669	1.834581	3.164898	2.446108	8.956119	3.057635	18									
119	0.791867	0.611987	1.577252	1.223974	2.372601	1.835961	3.163482	2.447948	8.954335	3.059935	16									
120	0.791511	0.612447	1.576335	1.224894	2.371533	1.837341	3.162064	2.449788	8.952555	3.062235	14									
121	0.791155	0.612907	1.575418	1.225814	2.370465	1.838721	3.160620	2.451628	8.950775	3.064535	12									
122	0.790798	0.613366	1.574500	1.226732	2.369394	1.840098	3.159192	2.453464	8.948990	3.066830	10									
123	0.790441	0.613826	1.573582	1.227652	2.368323	1.841478	3.157764	2.455304	8.947205	3.069130	8									
124	0.790084	0.614285	1.572664	1.228570	2.367252	1.842855	3.156336	2.457140	8.945420	3.071425	6									
125	0.789726	0.614744	1.571745	1.229488	2.366173	1.844232	3.154904	2.458976	8.943630	3.073720	4									
126	0.789368	0.615202	1.570826	1.230404	2.365104	1.845606	3.153472	2.460808	8.941840	3.076010	2									
127	0.789010	0.615661	1.570000	1.231322	2.364030	1.846983	3.152040	2.462644	8.940050	3.078305	0									
Degrees and Minutes.	Measured Distance, or Hypothenuse, 1, 10, 100, 1000, 10,000, or 100,000.				Measured Distance, or Hypothenuse, 2, 20, 200, 2000, 20,000, or 200,000.				Measured Distance, or Hypothenuse, 3, 30, 300, 3000, 30,000, or 300,000.				Measured Distance, or Hypothenuse, 4, 40, 400, 4000, 40,000, or 400,000.				Measured Distance, or Hypothenuse, 5, 50, 500, 5000, 50,000, or 500,000.			
	Distance from North or South.	Plane of Meridian.	Latitude or Longitude.	Distance from North or South.	Distance from North or South.	Plane of Meridian.	Latitude or Longitude.	Distance from North or South.	Distance from North or South.	Plane of Meridian.	Latitude or Longitude.	Distance from North or South.	Distance from North or South.	Plane of Meridian.	Latitude or Longitude.	Distance from North or South.	Distance from North or South.	Plane of Meridian.	Latitude or Longitude.	

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Degrees and Minutes.	Measured Distance, or Hypothesis, 1, 10, 100, 1000, or 100,000.				Measured Distance, or Hypothesis, 2, 20, 200, 2000, or 200,000.				Measured Distance, or Hypothesis, 3, 30, 300, 3000, or 300,000.				Measured Distance, or Hypothesis, 4, 40, 400, 4000, or 400,000.				Measured Distance, or Hypothesis, 5, 500, 5000, or 500,000.			
	Distance from Place of East or West.	Latitude or South.	Distance from Place of East or West.	Distance from Place of East or West.	Distance from Place of East or West.	Latitude or South.	Distance from Place of East or West.	Distance from Place of East or West.	Distance from Place of East or West.	Latitude or South.	Distance from Place of East or West.	Distance from Place of East or West.	Distance from Place of East or West.	Latitude or South.	Distance from Place of East or West.	Distance from Place of East or West.	Distance from Place of East or West.	Latitude or South.	Distance from Place of East or West.	Distance from Place of East or West.
1	0.78010	0.61569	1.57600	1.23132	2.36400	1.84698	3.15704	2.42624	3.97835	5.00000	3.81508	4.89476	5.98305	6.98305	7.98305	8.98305	9.98305	10.98305	11.98305	
2	0.78054	0.61619	1.57630	1.23228	2.36430	1.84734	3.15734	2.42654	3.97865	5.00030	3.81538	4.89506	5.98335	6.98335	7.98335	8.98335	9.98335	10.98335	11.98335	
3	0.78098	0.61670	1.57660	1.23324	2.36460	1.84770	3.15764	2.42679	3.97896	5.00060	3.81572	4.89536	5.98365	6.98365	7.98365	8.98365	9.98365	10.98365	11.98365	
4	0.78142	0.61721	1.57690	1.23420	2.36490	1.84806	3.15794	2.42704	3.97927	5.00090	3.81606	4.89566	5.98395	6.98395	7.98395	8.98395	9.98395	10.98395	11.98395	
5	0.78186	0.61772	1.57720	1.23516	2.36520	1.84836	3.15824	2.42729	3.97957	5.00120	3.81640	4.89596	5.98425	6.98425	7.98425	8.98425	9.98425	10.98425	11.98425	
6	0.78230	0.61823	1.57750	1.23612	2.36550	1.84866	3.15854	2.42754	3.97987	5.00150	3.81674	4.89626	5.98455	6.98455	7.98455	8.98455	9.98455	10.98455	11.98455	
7	0.78274	0.61874	1.57780	1.23708	2.36580	1.84896	3.15884	2.42779	3.98017	5.00180	3.81708	4.89656	5.98485	6.98485	7.98485	8.98485	9.98485	10.98485	11.98485	
8	0.78318	0.61925	1.57810	1.23804	2.36610	1.84926	3.15914	2.42804	3.98047	5.00210	3.81742	4.89686	5.98515	6.98515	7.98515	8.98515	9.98515	10.98515	11.98515	
9	0.78362	0.61976	1.57840	1.23900	2.36640	1.84956	3.15944	2.42829	3.98077	5.00240	3.81776	4.89716	5.98545	6.98545	7.98545	8.98545	9.98545	10.98545	11.98545	
10	0.78406	0.62027	1.57870	1.24000	2.36670	1.84986	3.15974	2.42854	3.98107	5.00270	3.81810	4.89746	5.98575	6.98575	7.98575	8.98575	9.98575	10.98575	11.98575	
11	0.78450	0.62078	1.57900	1.24096	2.36700	1.85016	3.16004	2.42879	3.98137	5.00300	3.81844	4.89776	5.98605	6.98605	7.98605	8.98605	9.98605	10.98605	11.98605	
12	0.78494	0.62129	1.57930	1.24192	2.36730	1.85046	3.16034	2.42904	3.98167	5.00330	3.81878	4.89806	5.98635	6.98635	7.98635	8.98635	9.98635	10.98635	11.98635	
13	0.78538	0.62180	1.57960	1.24288	2.36760	1.85076	3.16064	2.42929	3.98197	5.00360	3.81912	4.89836	5.98665	6.98665	7.98665	8.98665	9.98665	10.98665	11.98665	
14	0.78582	0.62231	1.57990	1.24384	2.36790	1.85106	3.16094	2.42954	3.98227	5.00390	3.81946	4.89866	5.98695	6.98695	7.98695	8.98695	9.98695	10.98695	11.98695	
15	0.78626	0.62282	1.58020	1.24480	2.36820	1.85136	3.16124	2.42979	3.98257	5.00420	3.81980	4.89896	5.98725	6.98725	7.98725	8.98725	9.98725	10.9		





### TRAVERSE TABLES.

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Distance from Meridian, or North or South.	Distance from Meridian, or North or South.	Distance from Meridian, or North or South.	Distance from Meridian, or North or South.	Distance from Meridian, or North or South.	Distance from Meridian, or North or South.	Distance from Meridian, or North or South.	Distance from Meridian, or North or South.	Distance from Meridian, or North or South.	Distance from Meridian, or North or South.
4	0.669180	1.388268	1.486288	2.294320	2.007390	2.675276	2.676520	3.716720	3.345650
5	0.669562	1.389240	1.486810	2.298265	2.007800	2.678100	2.678100	3.716720	3.345650
6	0.669946	1.390200	1.487350	2.302205	2.008210	2.681000	2.681000	3.716720	3.345650
7	0.670330	1.391160	1.487880	2.306145	2.008620	2.683900	2.683900	3.716720	3.345650
8	0.670715	1.392120	1.488410	2.310085	2.009030	2.686800	2.686800	3.716720	3.345650
9	0.671100	1.393080	1.488940	2.314025	2.009440	2.689700	2.689700	3.716720	3.345650
10	0.671485	1.394040	1.489470	2.317965	2.009850	2.692600	2.692600	3.716720	3.345650
11	0.671870	1.395000	1.490000	2.321905	2.010260	2.695500	2.695500	3.716720	3.345650
12	0.672255	1.395960	1.490530	2.325845	2.010670	2.698400	2.698400	3.716720	3.345650
13	0.672640	1.396920	1.491060	2.329785	2.011080	2.701300	2.701300	3.716720	3.345650
14	0.673025	1.397880	1.491590	2.333725	2.011490	2.704200	2.704200	3.716720	3.345650
15	0.673410	1.398840	1.492120	2.337665	2.011900	2.707100	2.707100	3.716720	3.345650
16	0.673795	1.399800	1.492650	2.341605	2.012310	2.710000	2.710000	3.716720	3.345650
17	0.674180	1.400760	1.493180	2.345545	2.012720	2.712900	2.712900	3.716720	3.345650
18	0.674565	1.401720	1.493710	2.349485	2.013130	2.715800	2.715800	3.716720	3.345650
19	0.674950	1.402680	1.494240	2.353425	2.013540	2.718700	2.718700	3.716720	3.345650
20	0.675335	1.403640	1.494770	2.357365	2.013950	2.721600	2.721600	3.716720	3.345650
21	0.675720	1.404600	1.495300	2.361305	2.014360	2.724500	2.724500	3.716720	3.345650
22	0.676105	1.405560	1.495830	2.365245	2.014770	2.727400	2.727400	3.716720	3.345650
23	0.676490	1.406520	1.496360	2.369185	2.015180	2.730300	2.730300	3.716720	3.345650
24	0.676875	1.407480	1.496890	2.373125	2.015590	2.733200	2.733200	3.716720	3.345650
25	0.677260	1.408440	1.497420	2.377065	2.016000	2.736100	2.736100	3.716720	3.345650
26	0.677645	1.409400	1.497950	2.381005	2.016410	2.739000	2.739000	3.716720	3.345650
27	0.678030	1.410360	1.498480	2.384945	2.016820	2.741900	2.741900	3.716720	3.345650
28	0.678415	1.411320	1.499010	2.388885	2.017230	2.744800	2.744800	3.716720	3.345650
29	0.678800	1.412280	1.499540	2.392825	2.017640	2.747700	2.747700	3.716720	3.345650
30	0.679185	1.413240	1.500070	2.396765	2.018050	2.750600	2.750600	3.716720	3.345650
31	0.679570	1.414200	1.500600	2.400705	2.018460	2.753500	2.753500	3.716720	3.345650
32	0.679955	1.415160	1.501130	2.404645	2.018870	2.756400	2.756400	3.716720	3.345650
33	0.680340	1.416120	1.501660	2.408585	2.019280	2.759300	2.759300	3.716720	3.345650
34	0.680725	1.417080	1.502190	2.412525	2.019690	2.762200	2.762200	3.716720	3.345650
35	0.681110	1.418040	1.502720	2.416465	2.020100	2.765100	2.765100	3.716720	3.345650
36	0.681495	1.419000	1.503250	2.420405	2.020510	2.768000	2.768000	3.716720	3.345650
37	0.681880	1.420000	1.503780	2.424345	2.020920	2.770900	2.770900	3.716720	3.345650
38	0.682265	1.420960	1.504310	2.428285	2.021330	2.773800	2.773800	3.716720	3.345650
39	0.682650	1.421920	1.504840	2.432225	2.021740	2.776700	2.776700	3.716720	3.345650
40	0.683035	1.422880	1.505370	2.436165	2.022150	2.779600	2.779600	3.716720	3.345650
41	0.683420	1.423840	1.505900	2.440105	2.022560	2.782500	2.782500	3.716720	3.345650
42	0.683805	1.424800	1.506430	2.444045	2.022970	2.785400	2.785400	3.716720	3.345650
43	0.684190	1.425760	1.506960	2.447985	2.023380	2.788300	2.788300	3.716720	3.345650
44	0.684575	1.426720	1.507490	2.451925	2.023790	2.791200	2.791200	3.716720	3.345650
45	0.684960	1.427680	1.508020	2.455865	2.024200	2.794100	2.794100	3.716720	3.345650
46	0.685345	1.428640	1.508550	2.459805	2.024610	2.797000	2.797000	3.716720	3.345650
47	0.685730	1.429600	1.509080	2.463745	2.025020	2.800000	2.800000	3.716720	3.345650
48	0.686115	1.430560	1.509610	2.467685	2.025430	2.803000	2.803000	3.716720	3.345650
49	0.686500	1.431520	1.510140	2.471625	2.025840	2.806000	2.806000	3.716720	3.345650
50	0.686885	1.432480	1.510670	2.475565	2.026250	2.809000	2.809000	3.716720	3.345650
51	0.687270	1.433440	1.511200	2.479505	2.026660	2.812000	2.812000	3.716720	3.345650
52	0.687655	1.434400	1.511730	2.483445	2.027070	2.815000	2.815000	3.716720	3.345650
53	0.688040	1.435360	1.512260	2.487385	2.027480	2.818000	2.818000	3.716720	3.345650
54	0.688425	1.436320	1.512790	2.491325	2.027890	2.821000	2.821000	3.716720	3.345650
55	0.688810	1.437280	1.513320	2.495265	2.028300	2.824000	2.824000	3.716720	3.345650
56	0.689195	1.438240	1.513850	2.499205	2.028710	2.827000	2.827000	3.716720	3.345650
57	0.689580	1.439200	1.514380	2.503145	2.029120	2.830000	2.830000	3.716720	3.345650
58	0.689965	1.440160	1.514910	2.507085	2.029530	2.833000	2.833000	3.716720	3.345650
59	0.690350	1.441120	1.515440	2.511025	2.029940	2.836000	2.836000	3.716720	3.345650
60	0.690735	1.442080	1.515970	2.514965	2.030350	2.839000	2.839000	3.716720	3.345650







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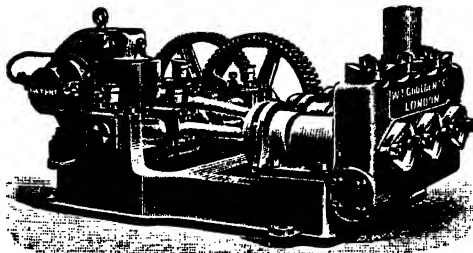
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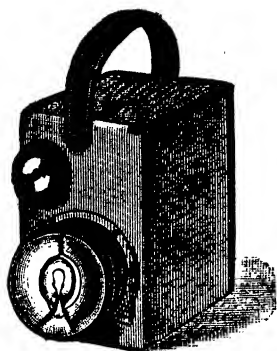
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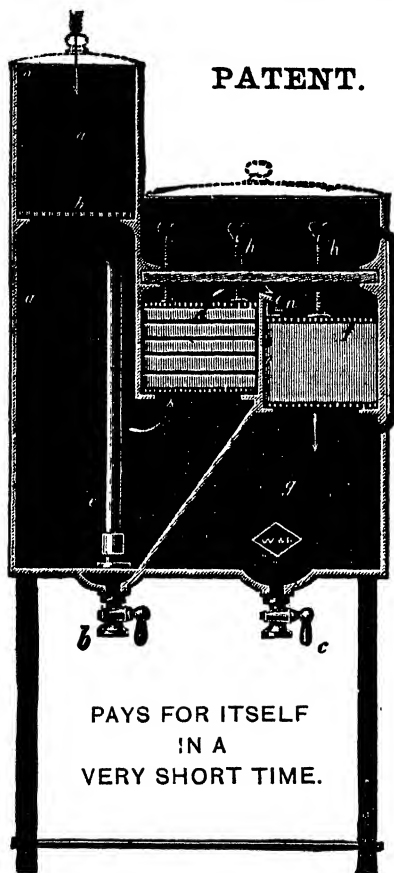
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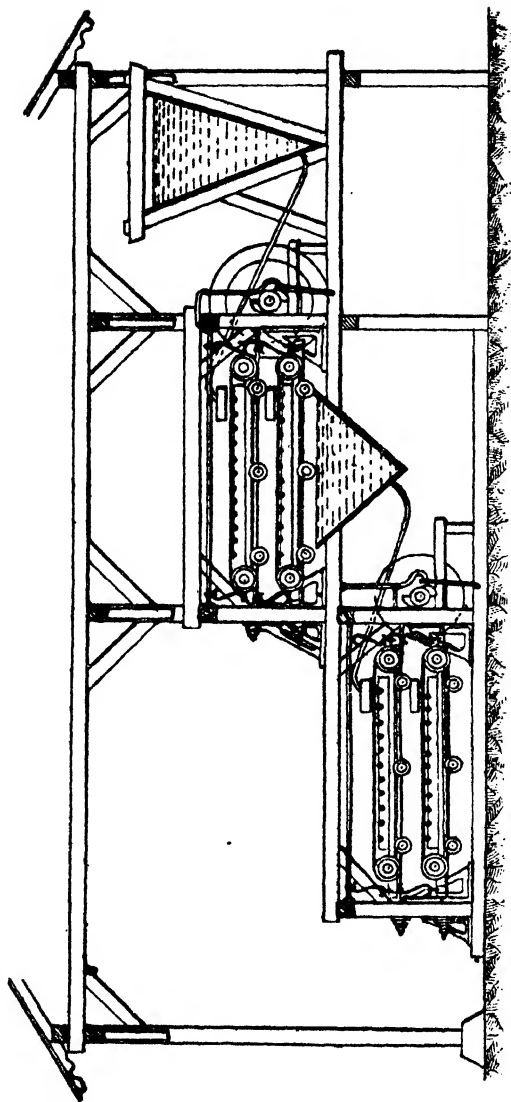
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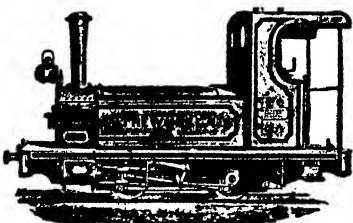
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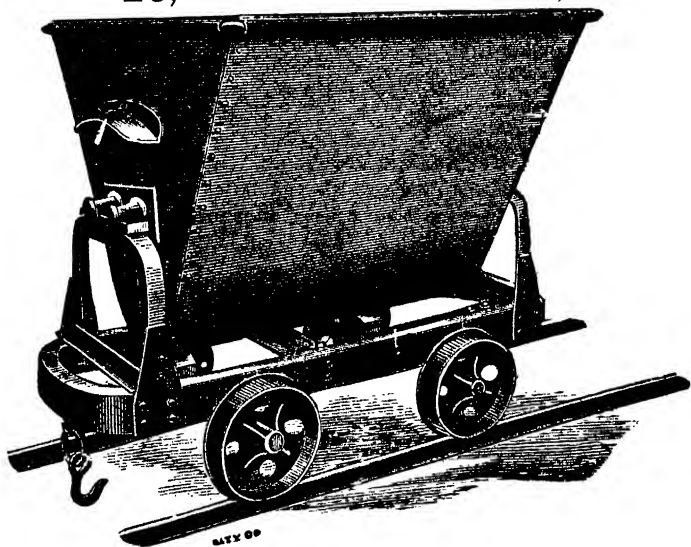
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